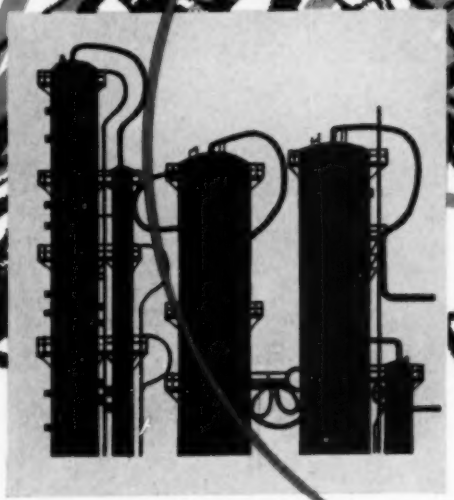
Chemical Engineering Progress

MAY 1954



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PIONEERS IN PETROCHEMICALS. Since the early 1920's Carbide and Carbon has been the trailblazer in what is now known as the "Petrochemicals Industry." In 1937, Carbide and Carbon put into commercial use its own process for the manufacture of ethylene oxide by direct oxidation. Since that time important improvements and modifications have been made in the original process and equipment which have resulted in marked technological advances. The development of the direct oxidation process is only one instance of Carbide and Carbon's accomplishments as "Pioneers in Petrochemicals."

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With four large plants now producing ethylene oxide by an exclusive process, CARBIDE assures you a continuous source of supply and quick delivery. Tank car, carload, and drum quantities of ethylene oxide are available for prompt shipment.

Rely on CARBIDE for this important chemical building block. Why? Because you can be sure that after 28 years of experience in producing ethylene oxide, CARBIDE can offer you consistent, high-quality material in the quantity you need—when you need it.

If you use ethylene oxide, call or write the nearest CARBIDE office for your copy of "Operating Procedures for Handling Ethylene Oxide." Ask for Form 7618. For information on ethers or other oxides, request Form 4764.

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Carbide and Carbon Chemicals Company
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30 East 42nd Street UCC New York 17, N. Y.

Chemical Engineering Progress

MAY, 1954

Volume 50, No. 5

Editor: F. J. Van Antwerpen

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Advertising Manager: L. T. Dupree

THIS MONTH'S COVER

In the artist's conception the nuclear pile in which atoms are fissioning is located at the extreme lower right. Overhead is a network of power lines in which electric power produced from the thermal energy of the pile is being distributed. Interposed between the two is a chemical processing unit, which is still awaiting development by chemical engineers. Upon this unit the critically needed economic advantage of nuclear power will greatly depend. The entire May issue of C.E.P. is devoted to this subject of nuclear energy, with chemical engineers' interests emphasized.

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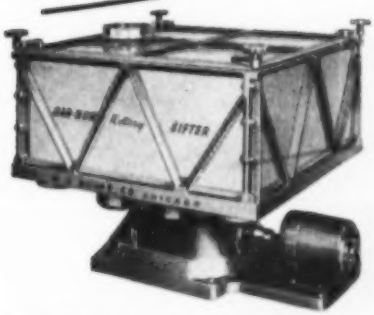
New



BAR-NUN Rotary Sifter

All-metal construction **assures sanitation, easy cleaning.**

New four-point drive **eliminates rods or flexible supports.**

Uniform rotary motion, mechanically controlled, yields thorough, clean separations—and big capacity per square foot of sieve area.

Exclusive features of this all-metal advanced model of the Bar-Nun Rotary Sifter especially recommend it to the chemical or food process plant.

The new and exclusive four-point drive imparts a controlled, uniform, single plane rotary motion over the entire screen area. This feature increases the yield of clean, accurate separations per square foot of screen area, and contributes to long life and low maintenance costs. Rods or flexible supports to carry the sifter box are eliminated.

The sifter box is constructed of cast aluminum frames, amply reinforced to carry full stress and centrifugal thrust. Side panels are of aluminum or stainless steel sheets, laminated to the structural aluminum frame. The box is dust-tight and sanitary, permitting no leakage. Easy cleaning is a feature; sieve frames are quickly removable for cleaning or washing when desired. A heavy-duty unit, the Bar-Nun Rotary Sifter is capable of continuous, 24-hour operation.

You can have the Bar-Nun in several different sizes, from one to four sieves deep, for two or more separations. Sieve frames may be wood, wood with metal lining or all metal, and clothed with wire, silk or nylon.

Write today for complete details on a Bar-Nun Rotary Sifter for any sifting or grading job in your process, where accurate separations and economical operation are important.

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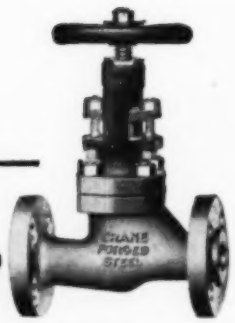
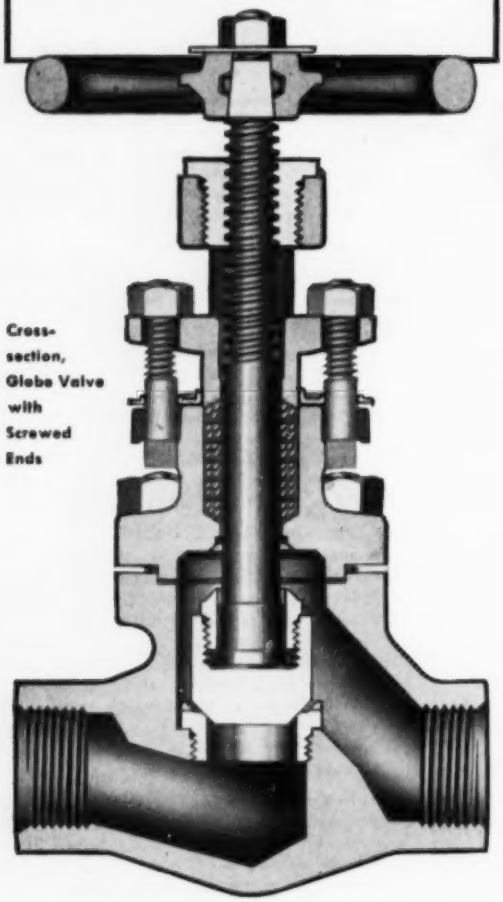


Flanged Ends
Globe and Angle Patterns

Screwed Ends
Globe and Angle Patterns

chlorine valves



Cross-section, Globe Valve with Screwed Ends

now regularly available with screwed ends *and* flanged ends

Take your choice of patterns in these Crane chlorine valves. They're *Crane Quality* throughout—designed exclusively for water-free chlorine gas or liquid up to 300° F.

In the cross-section you can see their strong, rugged construction—and the narrow bearing 45° taper disc and seat design that provides positive closure. Corrosion-resistant materials are used at all critical points. Disc, body seat ring and disc stem ring are durable Hastelloy "C." The stem and the gasket at the leak-proof bonnet joint are Monel. In the extra deep stuffing box there's laminated packing specially developed for chlorine service.

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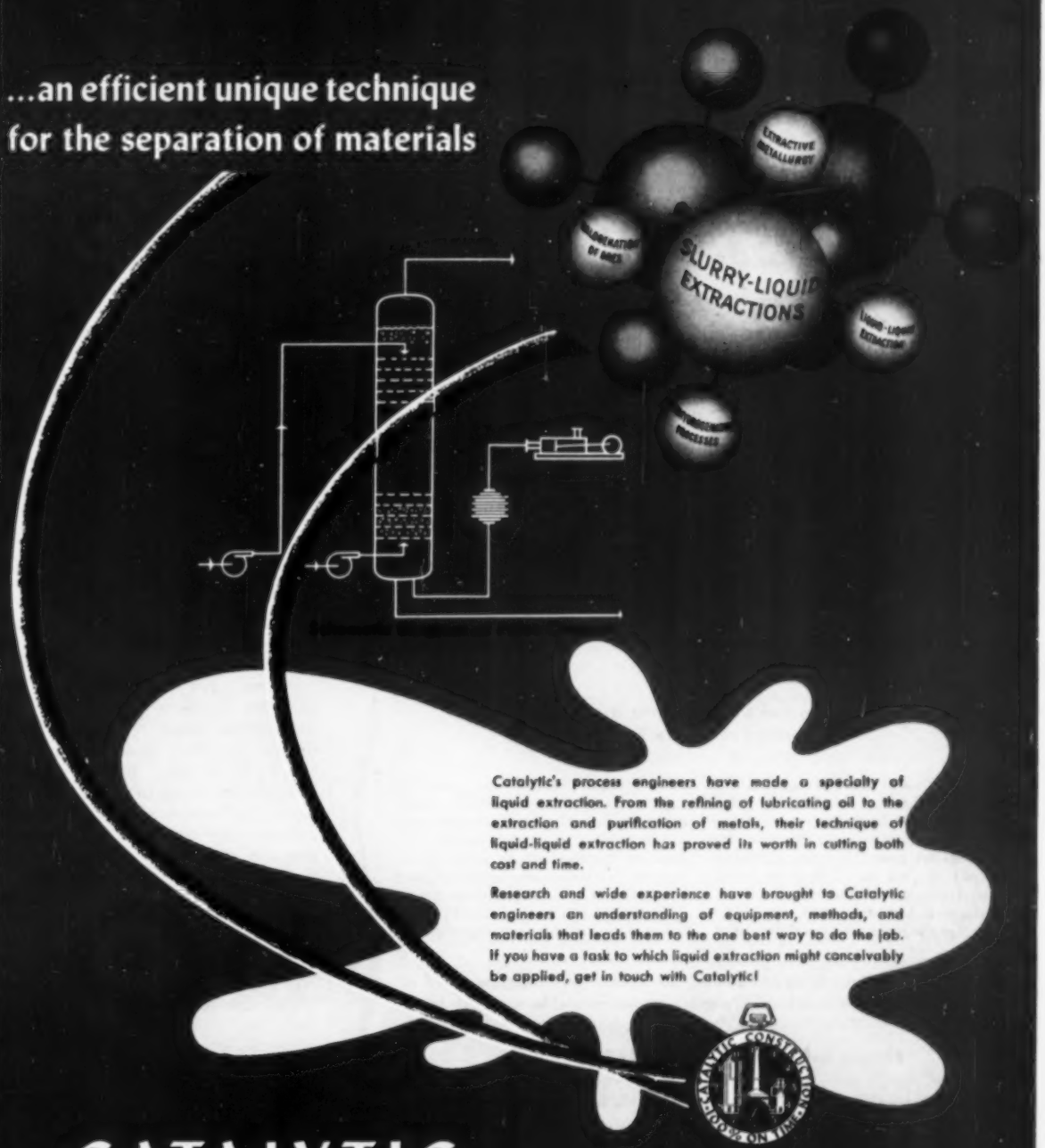

Catalytic's process engineers have made a specialty of liquid extraction. From the refining of lubricating oil to the extraction and purification of metals, their technique of liquid-liquid extraction has proved its worth in cutting both cost and time.

Research and wide experience have brought to Catalytic engineers an understanding of equipment, methods, and materials that leads them to the one best way to do the job. If you have a task to which liquid extraction might conceivably be applied, get in touch with Catalytic!

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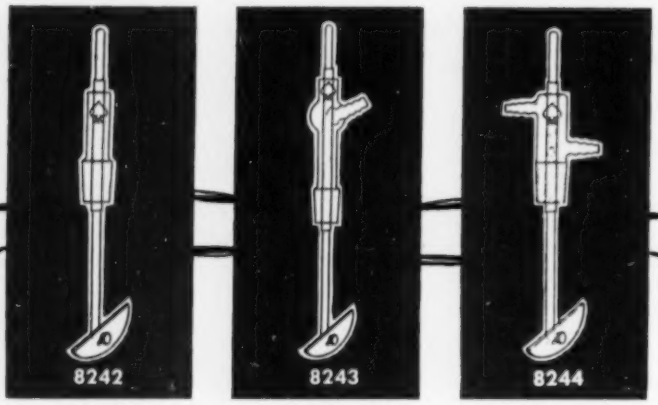

Imitation may be the sincerest flattery—but
You are entitled to the Ace Trubore Stirrer.

The Exclusive Ace Process provides the closest of rod and bearing tolerances—unmatched precision. Accurate tests show an average leak rate of but 6.4 mm. Hg/min. (unlubricated) at 760 mm. Hg/min. differential pressure. For lubricated stirrers, leakage is less than 0.05 mm. Hg./min. for the same pressure differential.

Ace Trubore Stirrers are made in various styles to meet unusual needs, such as a unit which permits the inert gas to be fed into and over the contents of the flask while stirrer is in motion. This same unit is also adapted to gas-liquid or liquid-solid reactions. All bearings and rods of Ace Trubore Stirrers are fully interchangeable.

ACE Trubore Stirrer Rods and bearing are stocked in a complete range of standard taper joints, and ACE standard interchangeable spherical joints.

Blades are available in TEFLON or Glass

When it comes to stirrers, don't be satisfied with less than the Original and Genuine ACE TRUBORE Stirrer . . . the finest . . . the most widely used . . . the most versatile . . . and truly economical.

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VINELAND NEW JERSEY

NOTED AND QUOTED

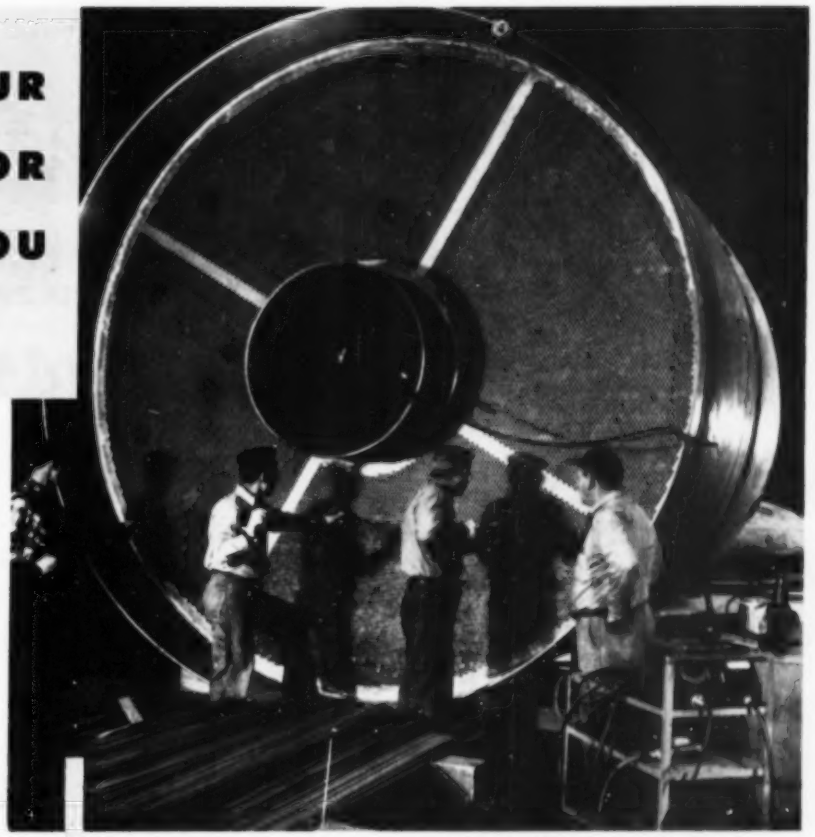
That Unallayed Thirst for Knowledge!

There is a reason for the search for knowledge which is inherent in the nature of man himself. The motivation which urges scientific men forward is the faith that it is good for man to understand, that this is his mission. The human race is, from one point of view, an incidental excrescence in an enormous and heartless cosmos, We crawl upon a rock which hurtles through space, doomed to struggle with one another in accordance with an inexorable law of evolution, bound for extinction as the earth grows cold, unsung and unremembered, our greatest works but the meaningless scratching upon the walls of the prison in which we are confined. But there is another side to the coin. Man, in his dignity, looks out upon the cosmos and fathoms it. He examines distant galaxies by light which left them a half billion years ago. He traces several billion years into the past, and gropes toward an understanding of the universe as a time-space complex, with a strange geometry which renders it invariant to the point of observation. He constructs his cosmic geometry as the projection of a four-dimensional space configuration, the shadow of which alone he can grasp. He turns inward, breaks down his molecules to atoms, then to protons, neutrons, and electrons, watches and manipulates the alterations of these into new and strange entities of brief existence. He probes for the ultimate forces which control the form of the nucleus, and thereby control all matter. Moreover, he turns upon himself and examines the mechanisms by which nerves act, the mechanisms by which the brain itself remembers, combines, and controls. And as he does all this he marvels none the less at the great central fact of existence, that he has a consciousness which enables him to comprehend.

It is good for man thus to search for understanding. His search will lead him into dangers, and he may not avoid th m. But even disaster, a temporary reversal of the trend which we call progress, is preferable to the monotonous existence of a vegetable. We are embarked upon a great adventure, not of our own choosing or making. It holds perils, and the things we learn may dismay us. But there is a deep meaning to consciousness, even if we cannot grasp it. There is a reason for

(Continued on page 10)

KNOW YOUR FABRICATOR BEFORE YOU BUY



Nooter boilermakers inserting copper tubes in Reboiler Section of Large Stainless Steel Column

One of a series designed to introduce you to

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what is PRICE?

Price can mean a lot of things—bargain . . . value . . . quality . . . investment.

To the processor looking for a "bargain basement" type of operation for his custom fabrications, Nooter is frankly not the choice—Nooter prices are seldom the lowest. On the other hand, to the processor for whom budget *is* an important consideration, Nooter prices are rarely the highest. But certainly for *all* processors, who want the fullest value for every dollar spent, *Nooter means the finest materials and workmanship, at* any *price!*

A Nooter fabrication always means a lot of features that you can't buy, yet features that add immeasurably to the final value of each job . . . such as highly specialized skills in working with the modern metals . . . unlimited work facilities . . . on-time deliveries that you can absolutely depend on, not merely plan around . . . these and more, at prices strictly competitive with services offering you *much* less.

May we prove what we say? Send us your blueprints. We're confident we can show you how Nooter prices can give you the *most* for your fabrication dollar.

Yours for the asking! "Beyond your Blue Prints," a comprehensive study of Nooter facilities, capacity and work scope.

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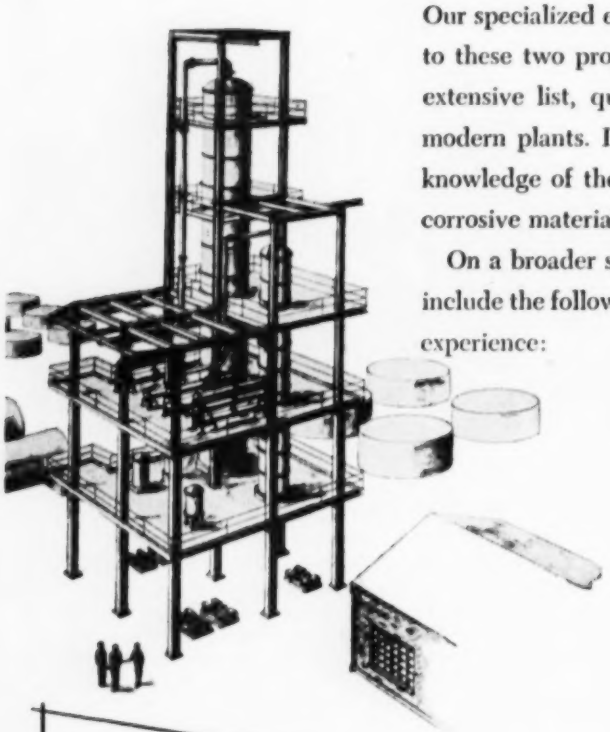
2 Current Projects of Interest

- **Catalytic Polymerization**
- **Secondary Butyl Alcohol Synthesis**



Our specialized experience with the chemical problems peculiar to these two projects, which have been selected from a rather extensive list, qualified us to design and construct these two modern plants. In particular, these processes require a special knowledge of the chemical reactions involved, the handling of corrosive materials and product separation.

On a broader scale our engineering and construction services include the following, in each of which we have had considerable experience:

Organic Chemical Synthesis

Inorganic Chemical Processing

Catalytic Operations

Solvent Purification

Separation and Refining of Organic Chemical Mixtures by conventional, azeotropic and extractive distillation, liquid-liquid extraction, crystallization

Petroleum Processing:
Topping and Vacuum Distillation
Lube Oil Units

Coal Tar Distillation

Gas and Vapor Recovery

Pharmaceuticals

If you have any plans involving a new plant or unit, expansion or modernization, we shall be glad to discuss them and outline our methods of procedure.

Engineering

Design and Construction of Process Plants

•

Design and Construction of Process Units

•

Process Evaluations

•

Economic Studies

BADGER MANUFACTURING COMPANY

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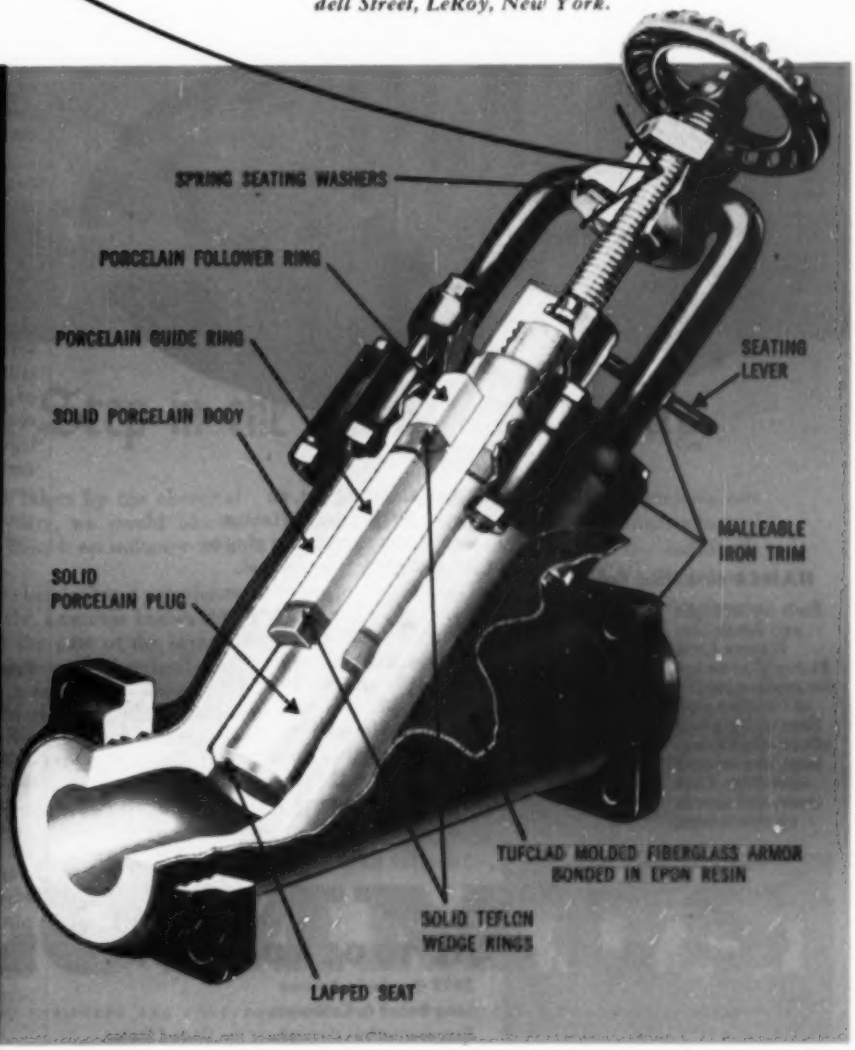
Non-ferrous working parts in the Lapp Valve eliminate freeze-ups from scales of corrosion. Threaded stud, yoke bushing and nuts, and plug cap are all brass or bronze, which keep the valve smoothly operative in all but the most unusual conditions of chemical atmosphere. Flange, yoke and gland are of high strength malleable or ductile iron, and are protected with baked-on Epon-base acid-proof paint. Flanges are permanently bonded to porcelain or armor with acid-proof resin cement. *Write for bulletin with complete description, characteristics, and specifications. Lapp Insulator Co., Inc., Process Equipment Division, 332 Wendell Street, LeRoy, New York.*

Y-valves, angle valves, flush valves, safety valves, and plug cocks of Lapp Porcelain have standard bolt-circle flanges for easy connection to all piping and equipment.



Lapp

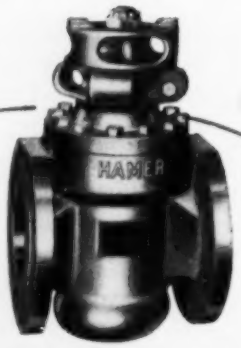
PROCESS EQUIPMENT

Chemical Porcelain Valves
Pipe • Raschig Rings • Pulsafeeder
Chemical Proportioning Pumps

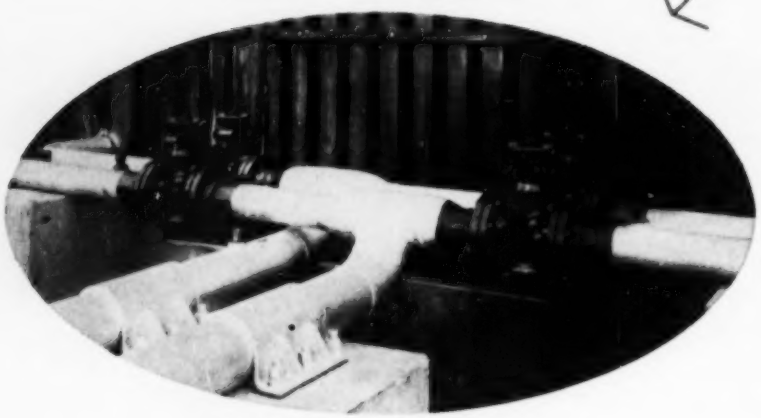
HAMER

PLUG VALVES

can't stick!



Model FS15P illustrated here has Pressure Seal packings which require neither tightening nor adjustment.



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The plug adjusting nut, an exclusive feature on all HAMER PLUG VALVES permits the plug to be lifted slightly from its seat, making it easy to open or close the valve. A simple turn lowers the plug back into its seat and holds it there in perfect alignment. No matter what the service conditions, or lapse of time between operations, this outstanding HAMER feature assures POSITIVE E-Z turn control of the plug at all times.

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NOTED AND QUOTED

(Continued from page 6)

man's search for understanding which extends beyond his immediate needs for food and shelter. This reason is his inherent urge to know. We share the great adventure with one another. Let us together pursue science for the practical benefits it may yield. But let us pursue it also because we would rise above the sordid daily struggle with nature and with ourselves, look out upon the universe in which we find ourselves, and down into its intricacies. Let us pursue science because we respond to the urge which lies deep in all of us to press on toward greater understanding.

Vannevar Bush
Today's Research and Tomorrow's World
Speech at Stanford Research Institute

Does the Engineer Know Patent Law?

. . . The engineer ought to know something about the care and handling of intellectual property, for that is a thing in which he and his employer must deal.

The right to copy the product of the mind of another is affected by the laws of patents, of copyrights, and of trademarks. . . .

In these confusing days of complex national and international problems, the engineer cannot afford to forget basic economic facts so clear to his predecessors a half century ago. Competition still exists, still carries with it the risks of loss and of possible ruin. Few reasons exist for not employing every legal advantage to meet these risks. One such advantage is the exclusive position provided by the limited patent monopoly specifically authorized by the government. . . .

R. H. MacCutcheon
The Engineer and Intellectual Property
Electrical Engineering

Freedom and the Arts

We are confused over the very meaning of the phrase "liberal arts," let alone the subjects of study for which it stands. It has acquired connotations of special privilege and preciosity. At the risk of laboring the obvious, therefore, let us recall that . . . the word "liberal" comes from the Latin *liber*, meaning "free"; that the proper meaning of the phrase "liberal arts" is "the arts becoming to a free man"; and that from earliest times these have included the sciences . . . . In other words the liberal

(Continued on page 14)

A Giant Step in the Chemical Industry

Among the giant steps taken by the chemical industry in the last 20 years, we would like to count MCA's decision to launch an industry-wide public relations program.

As builders of over 700 chemical and petroleum plants throughout the world, Lummus knows that greater understanding on the part of the layman will create greater acceptance of chemically-derived consumer products, a favorable community attitude toward location of chemical plants in an area, and an eagerness to work in and lend financial support to the industry. Lummus knows that an industry-wide public relations job will make the task of individual companies infinitely easier.

Although we are not producers of chemicals, our future as designers, engineers and constructors of manufacturing plants is linked to the industry's future. We wish all success to MCA's program.

THE LUMMUS COMPANY, 385 Madison Avenue, New York 17, N. Y. *Engineering and Sales Offices:* New York, Houston, London, Paris, Montreal. *Sales Offices:* Chicago, Caracas. *Heat Exchanger Plant:* Honesdale, Pa. *Fabricated Piping Plant:* East Chicago, Indiana.

CHEMICAL PROGRESS WEEK-MAY 1950

LUMMUS

DESIGNING ENGINEERS AND CONSTRUCTORS FOR THE PETROLEUM AND CHEMICAL INDUSTRIES

for either of these
CHEMICAL PUMPING
needs . . . specify
ALDRICH

AUTOMATICALLY CONTROLLED DELIVERY

MEDIUM to HIGH PRESSURE SERVICE

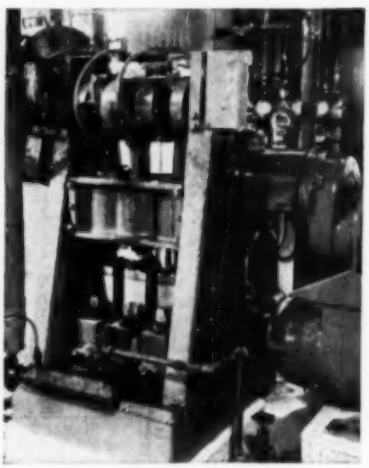
FOR AUTOMATICALLY CONTROLLED DELIVERY use an Aldrich-Groff "POWR-SAVR." This variable stroke triplex pump controls delivery from 0 to 100% of capacity at constant pump and motor speed . . . can be controlled from any remote point, manually or automatically. Power requirements are low, because consumption is directly proportional to demand.

"POWR-SAVR" pumps handle any free-flowing liquid at discharge pressures from 300 to 15,000 psi and are available in six sizes—from 2" to 6" stroke and from 5 to 125 bhp. For more information on these versatile pumps, write for Data Sheet 65.

FOR MEDIUM TO HIGH PRESSURE SERVICE several types of constant stroke pumps are available—depending upon the service involved. You may need the Inverted Vertical Triplex (Data Sheet 66), the Vertical Triplex (Data Sheet 26), or the Direct Flow Triplex or Multiplex Pump (Data Sheets 64, 64B). (All these helpful data sheets are available upon request.)

From our experience in building pumps for the chemical industry, we can—from our engineering and service files—frequently make specific recommendations to meet your chemical pumping needs. Whatever your problem, we welcome your inquiries.

Aldrich Pumps are ideal for applications involving corrosion, abrasive materials, high viscosity or high pressure. Among many liquids handled by Aldrich Pumps are: caustic solutions, fatty acids, nitric acid, acetic acid, aqua ammonia, anhydrous ammonia, as well as liquids encountered in the petroleum refining, petroleum chemical, and other industries.



This Aldrich Vertical Triplex Pump—on the job at the Burlington, N. J., plant of Hercules Powder Company—is employed to pump rosin ester in the manufacture of Abitol, hydroabietyl alcohol, used in lubricants and in the manufacture of alkyd resins. In this application pump capacity is one gallon per minute against 6,000 pounds discharge pressure.

THE ALDRICH PUMP COMPANY
20 GORDON STREET • ALLENTOWN, PENNSYLVANIA

. . . Originators of the Direct Flow Pump

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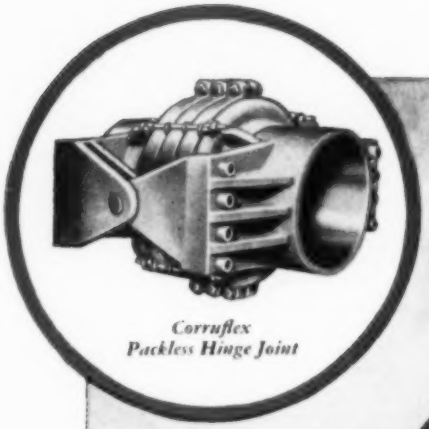


Corruflex Packless Hinge Joint

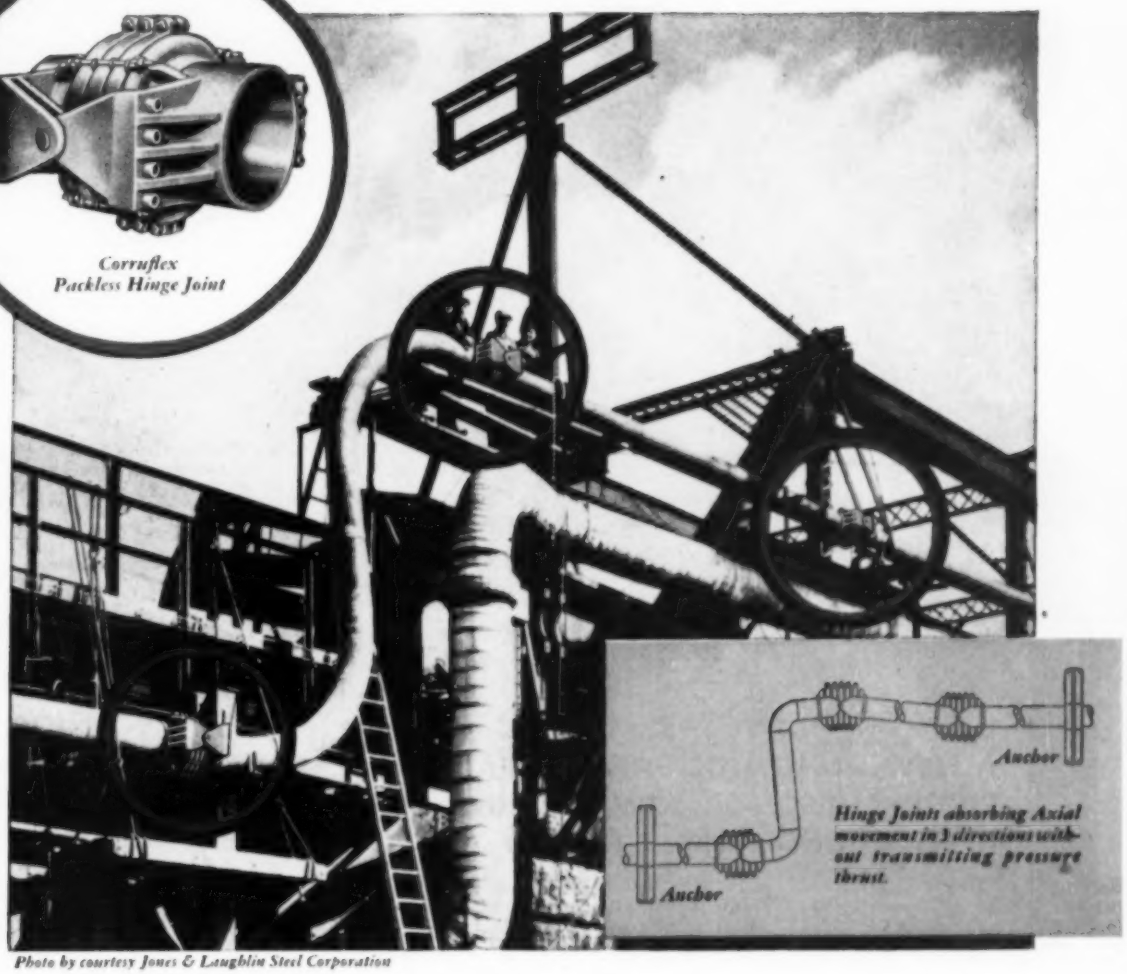


Photo by courtesy Jones & Laughlin Steel Corporation

HINGING A 14" STEAM LINE

● The Jones & Laughlin Steel Corp. in Pittsburgh last year had an excess of steam on one side of the Monongahela River and not enough on the other, where it was vitally needed. To correct this condition, J & L engineers planned to construct a high-pressure, superheated steam line along existing bridges and trestles to transmit the excess of steam to the other side.

However, a great difficulty soon appeared. If conventional expansion joints or loops were used at the 90° turns, pressure thrusts at anchor points would have been great enough to damage the bridges and trestles and actually cause these structures to collapse into the river.

Obviously, something else had to be used. With the aid of Adsco's Engineering Department, J & L "hinged" the pipe line with Corruflex Hinge Joints. These joints cannot develop pressure thrust because their two ends are held apart. They permit movement of a pipe line while keeping anchor loads at a minimum. When used properly, as pictured here, they will permit axial motion of one section of pipe line by permitting angular motion of another section.

Hinge Joints are only one type in the diversified Corruflex line of packless expansion joints. If you have a pipe expansion problem, consult Adsco. Making the world's most complete line of expansion joints, both slip and packless, Adsco will have the right answer.

ADSCO ENGINEERED PRODUCTS

AMERICAN DISTRICT STEAM COMPANY, INC.

GENERAL OFFICES
NORTH TONAWANDA, NEW YORK
PLANTS
NORTH TONAWANDA, N. Y., AND RICHMOND, CALIF.

Before Rupture
After Rupture
Because our standard angular type seat is retained with this design, this disc may be used with any existing BS&B Safety Head flanges you may now have in service. Also available in a complete assembly consisting of inlet and outlet flanges, rupture disc, studs and nuts.

BS&B

Announces

A NEW DESIGN OF SAFETY HEAD RUPTURE DISC FOR LOW PRESSURE APPLICATIONS MODELS 1A AND 1B

Here is a new BS&B Safety Head rupture disc especially developed for low pressure applications of a type which, because of extreme corrosive conditions, cannot be handled by our standard pre-bulged type of disc.

As you know, the BS&B Safety Head is a patented pressure relief device that is designed to become an integral part of any pressured system containing air, gas or liquid—either bland or corrosive.

Disc Models 1A and 1B are constructed of corrosion resistant metals such as Inconel, stainless steel, nickel, Hastelloy B and Monel, using a sealing membrane of Teflon or Kel-F. Either model is available in 2", 3", 4", 6", 8" and 10" sizes. Pressure ratings range from 8 to 100 lbs. Close design tolerances are an inherent feature of this type of disc.

Our knowledge attained by years of experience in the rupture disc field, combined with continuing research, development and a wide selection of controlled ductile metals has again enabled BS&B to provide industry with a time-proven product.

If you have a pressure relief problem which you have not been able to solve satisfactorily with the pre-bulged type of disc or other types of relief devices, we suggest that you investigate the BS&B Model 1A or 1B disc.

Your BS&B Man will be glad to give you details...or you may write for descriptive literature and prices.

BS&B Safety Heads

THE "CIRCUIT BREAKER" OF *Any Pressured System*

BLACK, SIVALLS & BRYSON, INC.
Safety Head Division, Dept. 2-DX5
7500 East 12th St., Kansas City 26, Mo.

SAFETY BS&B HEADS
OVER 60 YEARS

NOTED AND QUOTED

(Continued from page 10)

arts are rooted in freedom, not privilege, and they are broad, not narrow, in educational scope.

A. Whitney Griswold
The Free Economy of Students
Saturday Review of Literature

Science Makes Man

We have shown what man can make of science. Now it is a question of what our scientific environment will make of man, for an environment affects the form and the thought of each new generation.

Charles A. Lindbergh
Speech before the Institute of Aeronautical Sciences

Emergency Measure

At the time of our entry into World War I, a representative of the American Chemical Society called on the Secretary of War, Newton Baker, and offered the service of the chemists in the conflict. He was thanked and asked to come back the next day. On so doing, he was told by the Secretary of War that while he appreciated the offer of the chemists, he found that it was unnecessary as he had looked into the matter and found the War Department already had *a* chemist.

James B. Conant
Modern Science and Modern Man

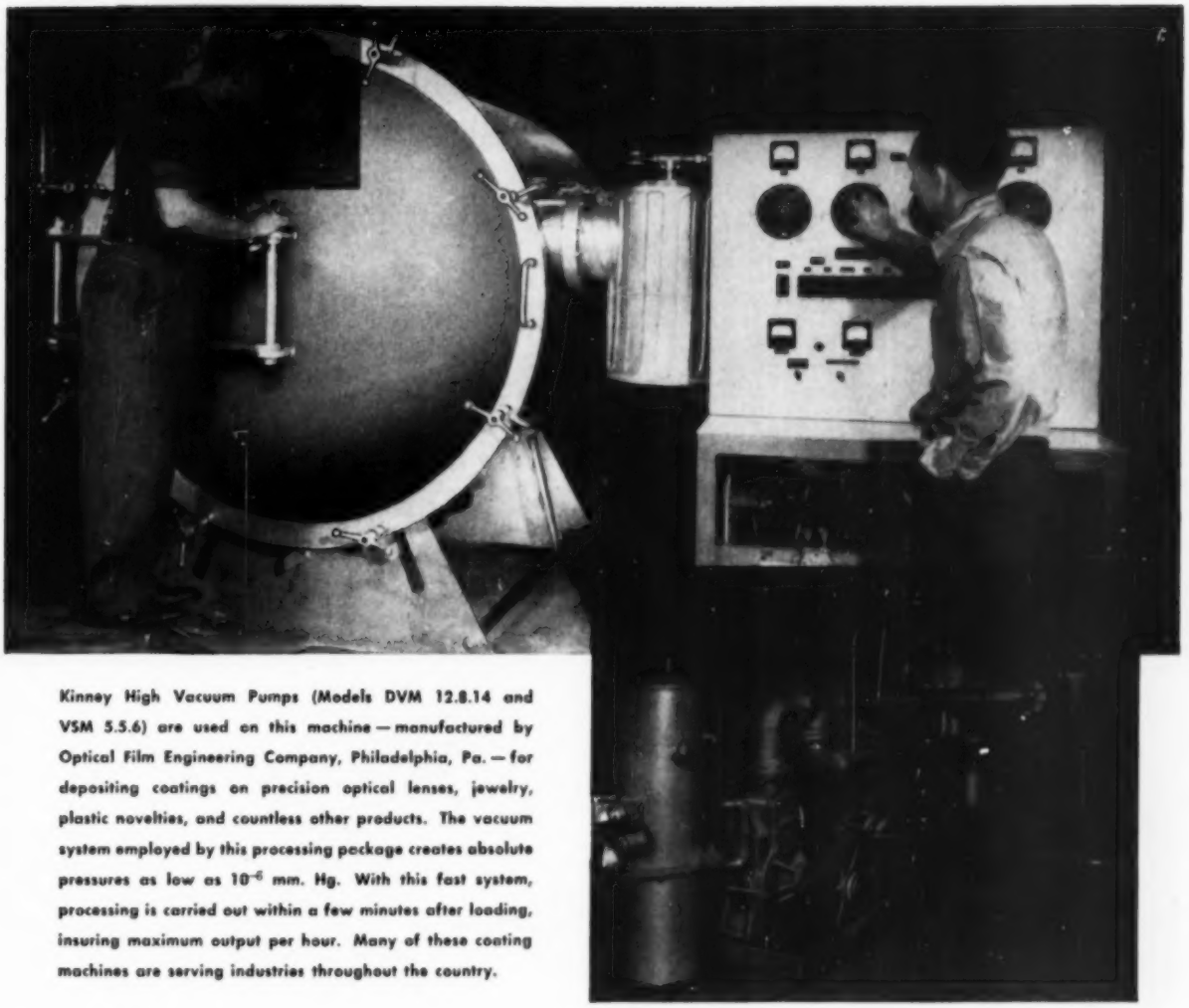
The Human Factor

Given an atmosphere in which people can and will do their best, there is no limit to what may be accomplished. Never has there been a clearer demonstration of that simple theorem than in this nation's history. Never has so much been accomplished in so short a span of years. And if we preserve for the future the spur of individual initiative, the horizons will be bright indeed. . . . Let us face the fact that advancing technology has not and will never change basic human nature. . . .

The need for competent people is increasing by leaps and bounds as our population grows and as the number of our cooperative ventures increases. It is a never-ending game of hide and seek—this question of finding competent leadership for government, for education, for our armies, for the arts, and for business and industry.

Crawford Greenewalt
DuPont Co.

(Continued on page 28)



Kinney High Vacuum Pumps (Models DVM 12.8.14 and VSM 5.5.6) are used on this machine — manufactured by Optical Film Engineering Company, Philadelphia, Pa. — for depositing coatings on precision optical lenses, jewelry, plastic novelties, and countless other products. The vacuum system employed by this processing package creates absolute pressures as low as 10^{-6} mm. Hg. With this fast system, processing is carried out within a few minutes after loading, insuring maximum output per hour. Many of these coating machines are serving industries throughout the country.

How to get the right vacuum pump

By consulting Kinney, you can choose from our line of 13 Single Stage and Compound vacuum pump models . . . the biggest, most versatile pump line on the market. We can help you size and apply these reliable high vacuum pumps to your vacuum processing operations. Our district offices are staffed with competent vacuum engineers, to assist you.

SEND COUPON TODAY!

KINNEY MFG. DIVISION
THE NEW YORK AIR BRAKE COMPANY
3548 WASHINGTON STREET • BOSTON 30 • MASS.

☐ Please send Bulletin V-51B describing the complete line of Kinney Vacuum Pumps.

Name .....
Company .....
Address .....
City ..... State .....

INCREASE throughput capacity
ELIMINATE costly liquid loss
IMPROVE overhead product quality
REDUCE harmful air pollution
with

YORKMESH DeMISTERS

CASE STUDY NO. 1002

CATALYST POISONING REDUCED 90%

OBJECTIVE:
To maintain high catalyst activity and increase catalyst life in the cracking unit by eliminating metal contamination due to liquid entrainment in the vacuum tower.

PROBLEM:
Excessive amounts of vanadium and nickel were being entrained in the vacuum tower overhead and sidedraw streams. When these gas oils were fed to the cat cracking units, the life of the catalyst was materially shortened. This meant high catalyst circulation rates, excessive attrition and greater catalyst make up. Deposition of metals also caused periodic drops in product yields; a reduction of 60% in butanes and butenes and 20% in gasoline yields was experienced on occasions. Accompanying increased rate of carbon build up on the catalyst particles at the same time made regeneration more difficult.

SOLUTION:
A 4" thick type 316 stainless steel Yorkmesh Demister installed two feet below the sidedraw accumulating channel eliminated the contaminating liquid entrainment.

RESULTS:
Metal contamination was reduced by over 90% and catalyst life was substantially extended.

COMPARISON OF METALS CONTENT BEFORE AND AFTER INSTALLATION OF YORKMESH DEMISTER

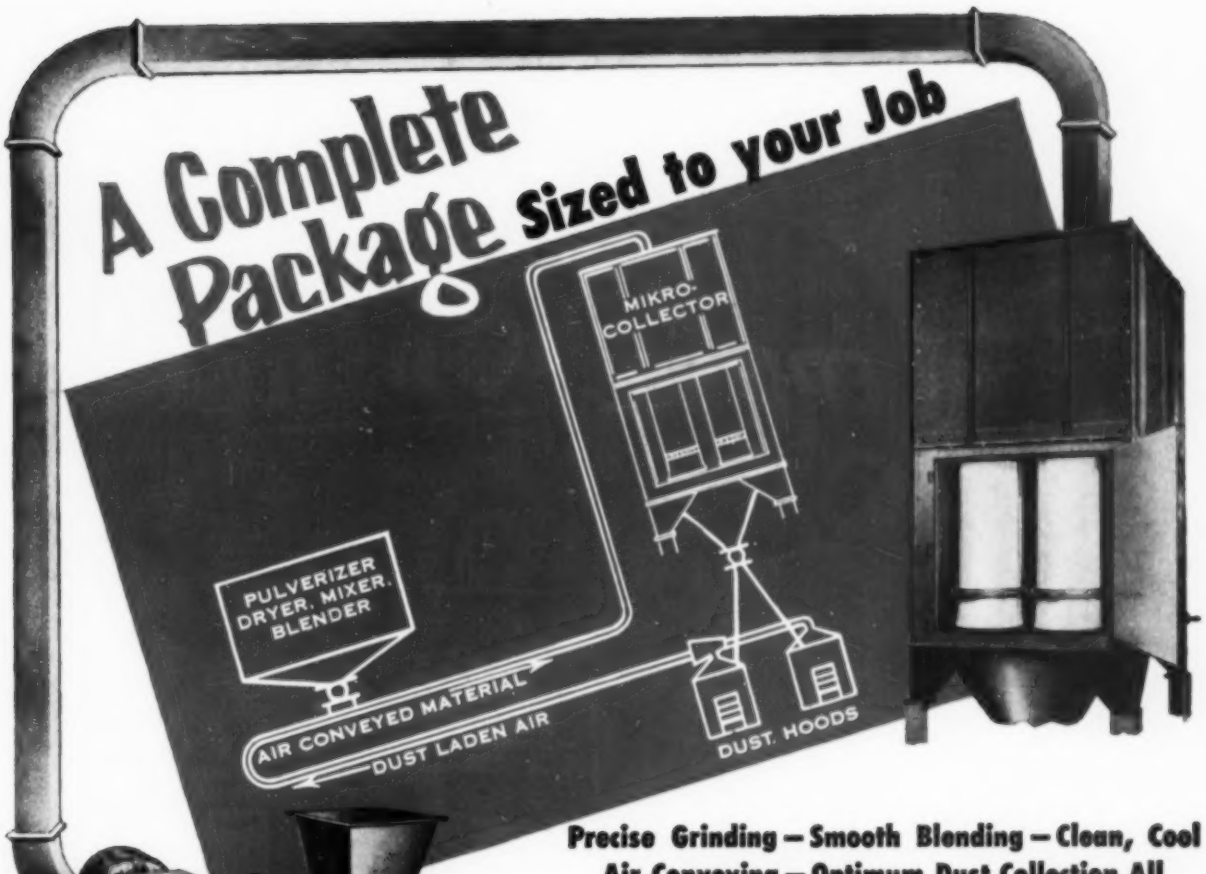
Sidedraw Stream (Ppm)	Before	After
Vanadium	30	3
Nickel	28	3
Ash	136	9.6
Overhead Stream (Ppm)	**Before**	**After**
Vanadium	2.0	0.09
Nickel	2.0	0.03
Ash	18	4.3

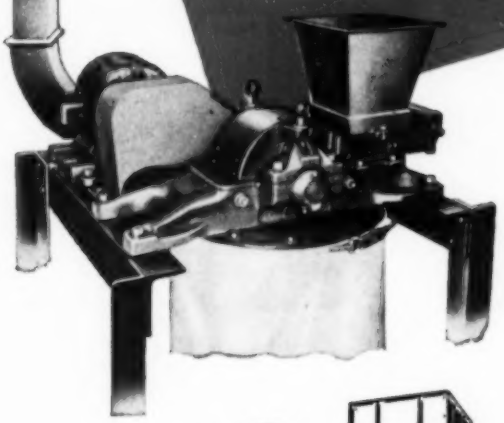
Note: For full story of how this single 4" Yorkmesh Demister pad reduced metal contamination by over 90% write for case study No. 1002

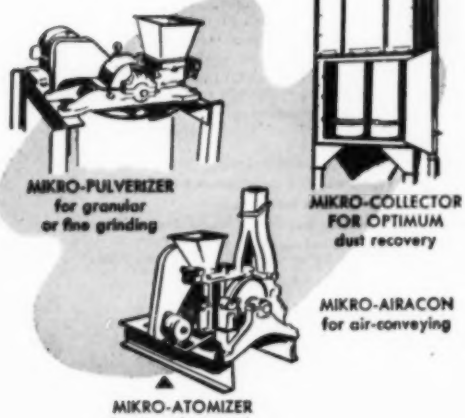
YORK

OTTO H. YORK CO., INC.
69 GLENWOOD PLACE. EAST ORANGE. N. J.

A Complete Package Sized to your Job






MIKRO-PULVERIZER for granular or fine grinding
MIKRO-COLLECTOR FOR OPTIMUM dust recovery
MIKRO-AIRACON for air-conveying
MIKRO-ATOMIZER for ultra-fine grinds

Precise Grinding — Smooth Blending — Clean, Cool Air Conveying — Optimum Dust Collection All Unified In a Single MIKRO System

This One-Package MIKRO method of engineering welds three separate functions into a coordinated and completely automatic processing system which eliminates the cost of manual handling. It guarantees the delivery of a product to meet your most exacting specifications without any loss of material in process.

The basic grinding unit . . . either a MIKRO-PULVERIZER or a MIKRO-ATOMIZER . . . blends and grinds with ease, safety and economy and offers you a wide range of particle sizing from granular to ultra-fines.

The ground material is whisked away by the MIKRO-Airacon from any given source to any point of discharge.

In the MIKRO-COLLECTOR, where the material is filtered the reverse-jet air ring operation provides the maximum in product recovery. Here you have granular and fine powder collection at its best.

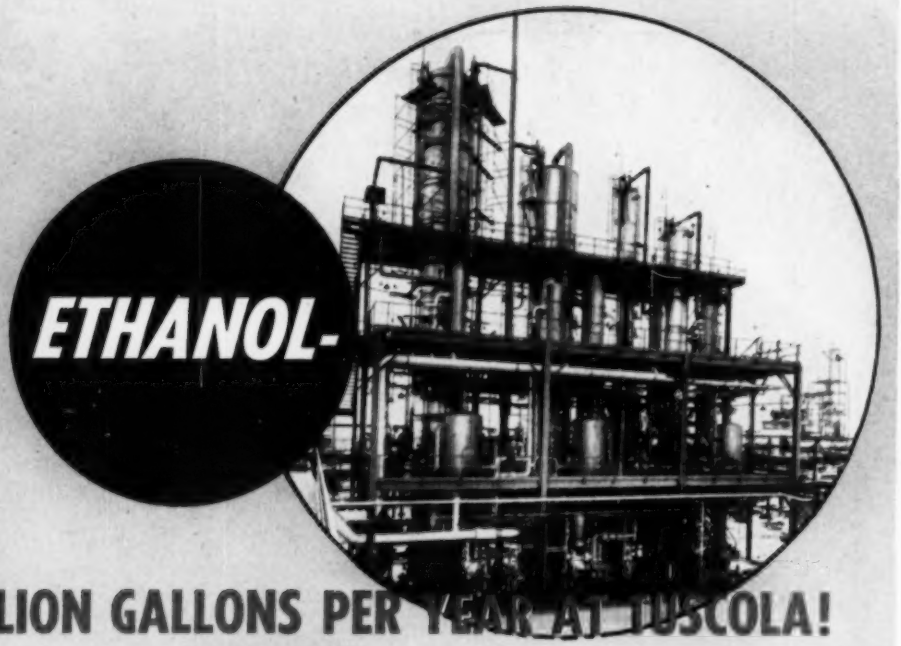
This complete MIKRO "package" thus affords you an answer to many processing and materials handling problems. The service and facilities of the MIKRO Laboratory are at your disposal, without obligation, to help obtain the best answer for you.

Write for illustrated descriptive literature.

MIKRO

PULVERIZING MACHINERY DIVISION
METALS DISINTEGRATING COMPANY, INC.
31 CHATHAM ROAD SUMMIT, NEW JERSEY

2160



ETHANOL-

40 MILLION GALLONS PER YEAR AT TUSCOLA!

RESULTS —

Lower Plant Investment

Lower Operating Costs

On Stream — On Time!

Vulcan's basic Process Knowledge and complete Engineering Service made possible this Synthetic Ethanol Plant for National Petro-Chemicals at Tuscola, Ill.

Vulcan Engineering is proud of its major contribution to the huge, new plant of National Petro-Chemicals Corporation. From Vulcan's basic process knowledge, augmented by pilot plant studies, a process for ethanol synthesis has been developed which, at Tuscola, results in an installation of minimum investment and low-cost operation. It was up and ready to function the instant feed material could be brought to it.

SPECIAL FEATURES

Engineers will be interested in several special features of this synthesis plant:

1. *The largest single piece bonded lead-lined steel tower in the country* — possibly the world.
2. *Two complex special alloy-lined absorbers,* which — after manufacturing, shipping and site erection — tested without a single leak.
3. *Special corrosion problem licked.* Extreme corrosion tendencies of sulfuric acid at high temperatures overcome by Vulcan design.
4. *Substantial savings effected* by use of copper-lined steel pressure columns designed and built by Vulcan's Manufacturing Division.
5. *Over ⅓ of the total heat requirement saved* by special Vulcan-designed recovery system.

To other chemical and petro-chemical processors — Whether your interest is in a complete job like this or a more narrowly defined engineering problem, Vulcan Engineering can offer you experienced service in any or all of these areas:

- Preliminary evaluation
- Development and pilot plants
- Project engineering
- Procurement
- Process design and engineering
- Mechanical engineering
- Construction
- Initial operation

VULCAN ENGINEERING DIVISION

THE VULCAN COPPER & SUPPLY CO., *General Offices and Plant,* CINCINNATI 2, OHIO

NEW YORK BOSTON PHILADELPHIA SAN FRANCISCO

VICKERS VULCAN PROCESS ENGINEERING CO., LTD., MONTREAL, CANADA

DIVISIONS OF THE VULCAN COPPER & SUPPLY CO.:

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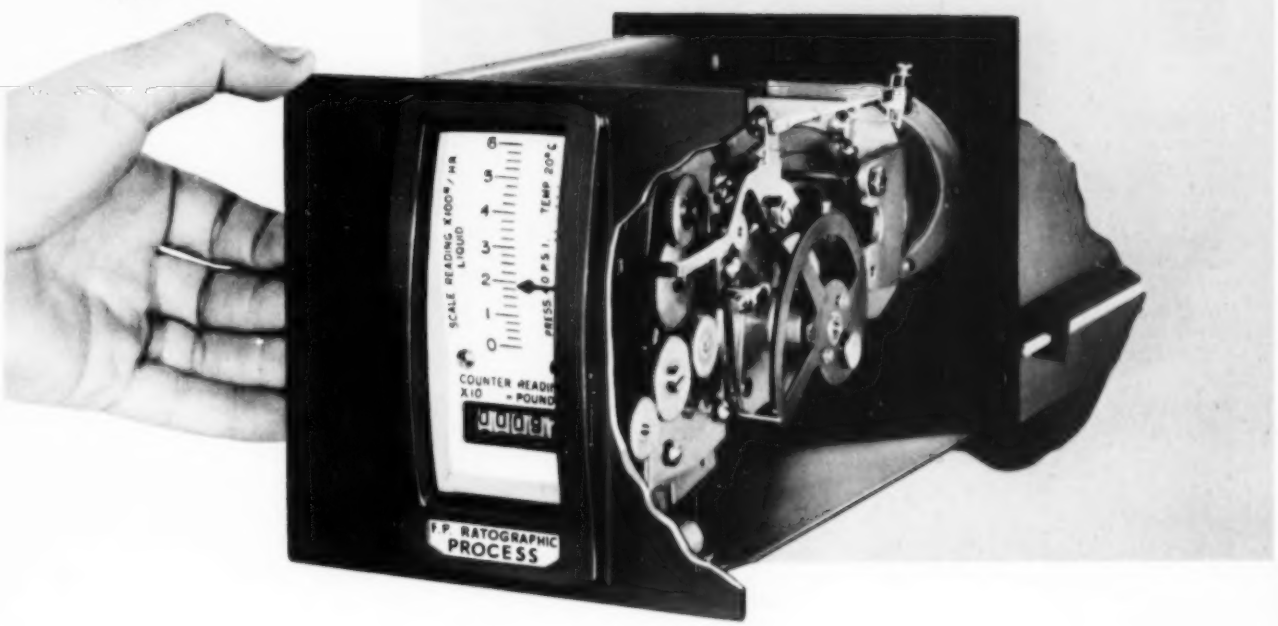
NEW

Ratographic* totalizer



complete with continuous rate indication

- continual integration at rate of 24 times per minute
- dust-proof drive mechanism immersed in oil
- heavy duty 100 rpm – 72 pole synchronous motor
- standard size pneumatic receiver and integrator
- front-of-panel accessibility and removal
- accuracy within 1% of full scale

Here, for the first time, is a *full-size*, rugged totalizer – so designed that it can be used in full size, miniature or graphic panels. A companion to the F & P Ratographic miniature indicator, it is another step in complete process instrumentation developed and perfected by the skilled engineers at Fischer & Porter Company.

The entire unit occupies only six inches square of panel space. In extended position, as shown, instrument continues to function, thus easily enables observation of mechanism. The highly accurate integrating unit gives the equivalent of continuous integration. The many other new features combined in this instrument suggest a careful comparison. Full information on request.

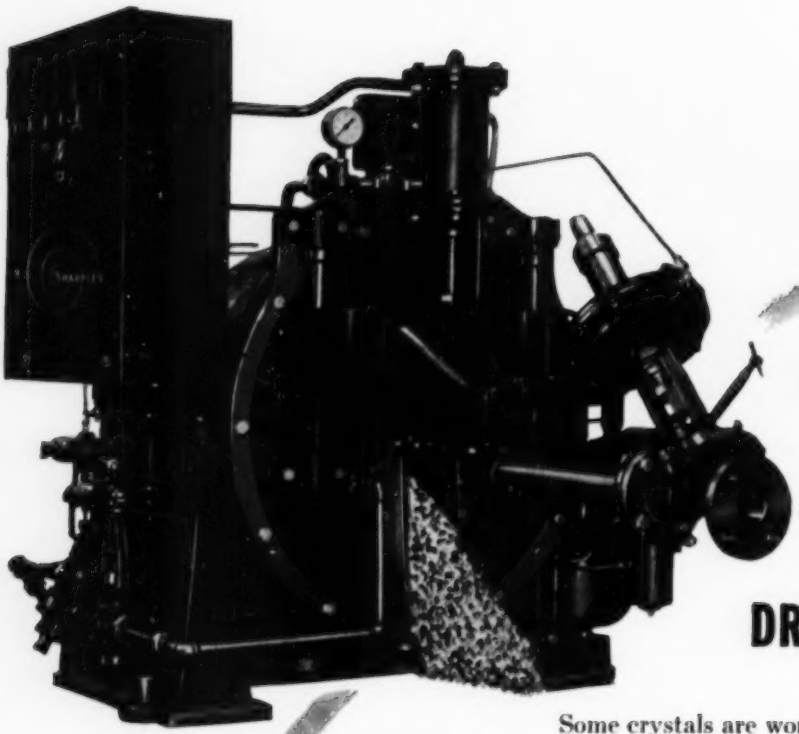
*T. M., F&P Co.

complete process instrumentation

FISCHER & PORTER CO.

1210 County Line Road, Hatboro, Penna.

Company owned sales and service branches strategically located throughout the world.



what price

DRY CRYSTALS?

Some crystals are worth dollars *per ton* like ammonium sulphate and caustic salt . . . others, such as procaine penicillin, are valued in terms of dollars *per gram*. In either case, the Sharples Super-D-Hydrator provides the maximum efficiency and flexibility for the production of high purity dry crystals. Every phase of the machine's continuous cyclic operation is regulated by remotely mounted adjustable controls.

What price crystal dehydration? Today, scores of Sharples Super-D-Hydrators are dehydrating up to 8 tons per hour of bulk crystals, and as little as a few hundred pounds per hour of antibiotic materials—at low cost, and to rigid specifications.

Sharples has specialized in crystal dehydration problems for over a quarter of a century. Our experience is at your command.

It will pay you to write for Bulletin 1257.

SHARPLES

THE SHARPLES CORPORATION • 2300 WESTMORELAND STREET • PHILADELPHIA 40, PA.
NEW YORK • PITTSBURGH • CLEVELAND • DETROIT • CHICAGO • NEW ORLEANS • SEATTLE • LOS ANGELES • SAN FRANCISCO • HOUSTON
Associated Companies and Representatives throughout the World

Advances in Applied Radiation

DEVELOPMENTS in the FIELD OF APPLIED RADIATION ENERGY, its APPLICATIONS and the APPARATUS USED TO PRODUCE IT

Radiation Facilities at High Voltage

The versatility of today's accelerators is demonstrated by the radiation power available to industry for experimental and process work at High Voltage's plant in Cambridge:

- Electron energies up to 2.25 MeV capable of delivering dosages of ionizing power up to 50 million gram rep per second — two hundred times greater than the *hourly* output of a kilocurie source of Cobalt. Our Van de Graaff facility can completely sterilize samples at rates up to 200 gross pounds of material per hour, or can deliver massive radiation doses to plastics or chemical systems on a continuous process basis.
- X-ray intensities up to 300 roentgens per minute at 50 cm. Both 1- and 2-million-volt x-rays are available for radiography or research.
- Positive ions (both protons and deuterons) in the range from 0.75 to 2.0 MeV at continuous beam currents up to 50 microamperes.
- Thermal neutron fluxes up to 5×10^{9} n/sec-cm^2.
- Monoenergetic neutrons from the kilovolt range up to 6 MeV.

Three accelerators in our plant are being used on a contract basis by major industrial companies. We believe these facilities are unmatched in the world today.

The Superiority of Particle Accelerators as Radiation Sources

As a company whose business is the practical application of radiation energy, it is High Voltage's job to investigate alternative sources of this energy — nuclear reactors, pile-produced radioactive sources, and the by-products of nuclear fission — as well as the particle accelerators. *For most applications, including research, the superiority of machine radiation sources is startling.*

Radioactive sources in the multi-megacurie range would have to be available at a cost, including shielding and transportation, of a few cents per curie before the power capabilities and costs of the accelerators *available today* could be matched for commercial use. Even in experimental research, electron sources have become a practical necessity where dynamic systems requiring high dose rates are involved. The very low output and absorption of gamma radiation from radioactive isotopes makes it impossible to produce useful yields in a reasonable period of time.

Long recognized as precision sources of a wide range of monoenergetic neutrons for research, today's Van de Graaff particle accelerators are also capable of producing, with virtually no gamma background, neutron fluxes which match those available at the experimental portals of large nuclear piles. Neutron fluxes of 10^{10} n/sec-cm^2 over a sphere of 10 cm in diameter appear feasible with today's accelerator technology, with equipment costs which are a fraction of those associated with the construction of a nuclear reactor.

New Tool for the Oil Industry

High Voltage's Model HN 0.5-million-volt Van de Graaff is now being used by Well Surveys, Inc., Tulsa, Oklahoma, in studying the scattering characteristics of radiation in soil strata.

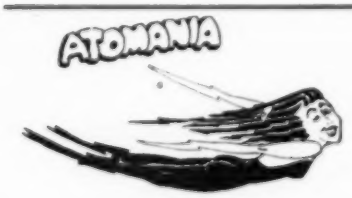
Well logging has become increasingly important in oil-well exploration, and today nearly all rotary-drilled wells are logged at least once before completion. Of all available techniques of logging, radioactivity logging, developed by Well Surveys, Inc., has proved to be the only method of locating and identifying subsurface formations in both open and cased holes. In the past, research in scattering characteristics has been carried out with radioactive isotopes, but these have lacked both the necessary intensity and the desired energy. Well Surveys' new Van de Graaff can produce a flux of neutrons as great as that from several hundred grams of radium-beryllium. With this compact accelerator, Well Surveys expects to gain more precise data for increasing the efficiency of oil-well completion and exploitation.

New Linear Accelerator

High Voltage has delivered the first microwave linear accelerator to be built commercially in the United States. Combining radar and accelerator techniques, this unit is controllable in energy from 10 to 50 million volts, and will be used to study the effectiveness of direct high-energy electron bombardment in cancer treatment. Completely engineered by High Voltage, it is based on designs of the Microwave Laboratory, Stanford University, and employs klystron amplifier tubes and wave guides developed and constructed at Stanford.

Radar pulses from the klystrons carry bursts of electrons along the 16-foot wave guide in which a very high vacuum is maintained. At the end of the guide, the electrons have attained a speed nearly equal to that of light and weigh 100 times more than when they started. A thin aluminum window maintains vacuum in the wave guide and allows the electron beam to be used externally in cancer-treatment research.

With the successful completion of this apparatus — the first linear accelerator for medical use in this country — High Voltage has added both a new product and a new technology to its versatile line of accelerators for medicine, research, and industry.



This is an electron-
a negative personality but usually
very fast.

High Voltage Engineering Corporation

7 University Road — Cambridge 38, Massachusetts

The "inside" story of *ElectroniK* instruments

Maybe you've never seen what's inside the case of an *ElectroniK* instrument. And even if you have, you might not realize how each component has been painstakingly refined to contribute its share to the overall performance and dependability of the instrument. Three of these components in particular—the converter, "Continuous Balance" amplifier and the balancing motor—are key members of the *ElectroniK* team with which you should get acquainted.

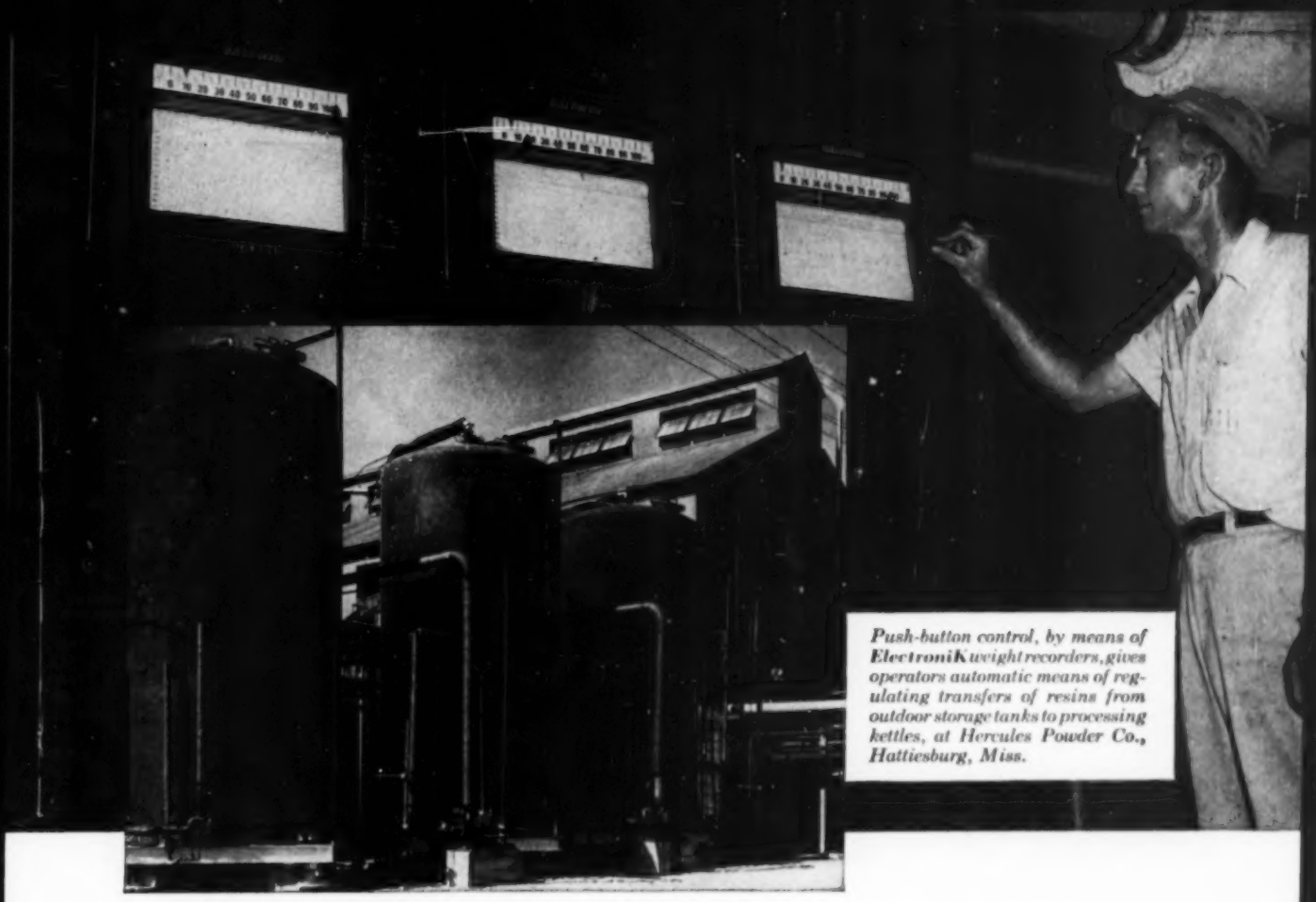
The Converter is what transforms tiny direct-current signals from the thermocouple or other sensing element into an alternating voltage that the amplifier can conveniently handle. In principle, it is somewhat like the vibrator in your automobile radio. But because it deals with such small bits of electrical energy, it has been designed of carefully selected materials which prevent the introduction of misleading signals into the measuring system. It is hermetically sealed against the effects of dust, humidity and atmospheric pressure change, and is shielded against stray electrical and magnetic fields.

The "Continuous Balance Amplifier" boosts the incoming signals by millions of times . . . makes them strong enough to operate the balancing motor. Although it looks like part of a radio chassis, few communications circuits could equal it for quality. It uses standard, easily obtained parts, which are operated far below their normal ratings to insure exceptionally long life. The circuit has great stability against drift and pick-up, and is thoroughly temperature compensated.

The Balancing Motor does the work of moving the pointer, recording pen and any control devices that may be incorporated in the instrument. It packs plenty of power into a small space . . . gives ample torque to give fast, accurate positioning whenever the amplifier calls on it. Totally enclosed, the motor is impervious to dust, dirt and changes in mounting position.

Electrical weighing system measures batch

Four Baldwin-Lima-Hamilton SR-4 load cells like this one are built into the pillar mounts of the storage tanks. Connected in series to an ***ElectroniK*** *recorder, they detect total weight of the tank. An adjustment in the instrument cancels out dead weight, to give direct reading of weight of tank contents.*



Push-button control, by means of ***ElectroniK*** *weight recorders, gives operators automatic means of regulating transfers of resins from outdoor storage tanks to processing kettles, at Hercules Powder Co., Hattiesburg, Miss.*

ingredients accurately . . . *automatically*

NEED to measure transfers of materials? The automatic weighing system that Hercules Powder Co. uses for measuring resin ingredients at their Naval Stores plant may give you some new ideas.

The problem here was to transfer the required weights of various viscous liquids from outdoor storage tanks into processing kettles. The answer is electrical weighing by means of a fully automatic system that utilizes Baldwin-Lima-Hamilton SR-4® strain gage load cells and *ElectroniK* strip chart controllers. This system controls weight directly without the complications that go with conventional flow metering.

Each tank is weighed continuously by four load cells mounted under the tank-supporting beams. Output of the load cells is fed to an *ElectroniK* weight recorder. To deliver a given amount of liquid into a processing kettle, the operator sets a selector switch and moves the instrument control index downscale by the required poundage. Pushing a button starts the cycle. Without further attention, the system pumps out the desired poundage of fluid, automatically stops the pump, records the weight delivered and steam-purges connecting pipes.

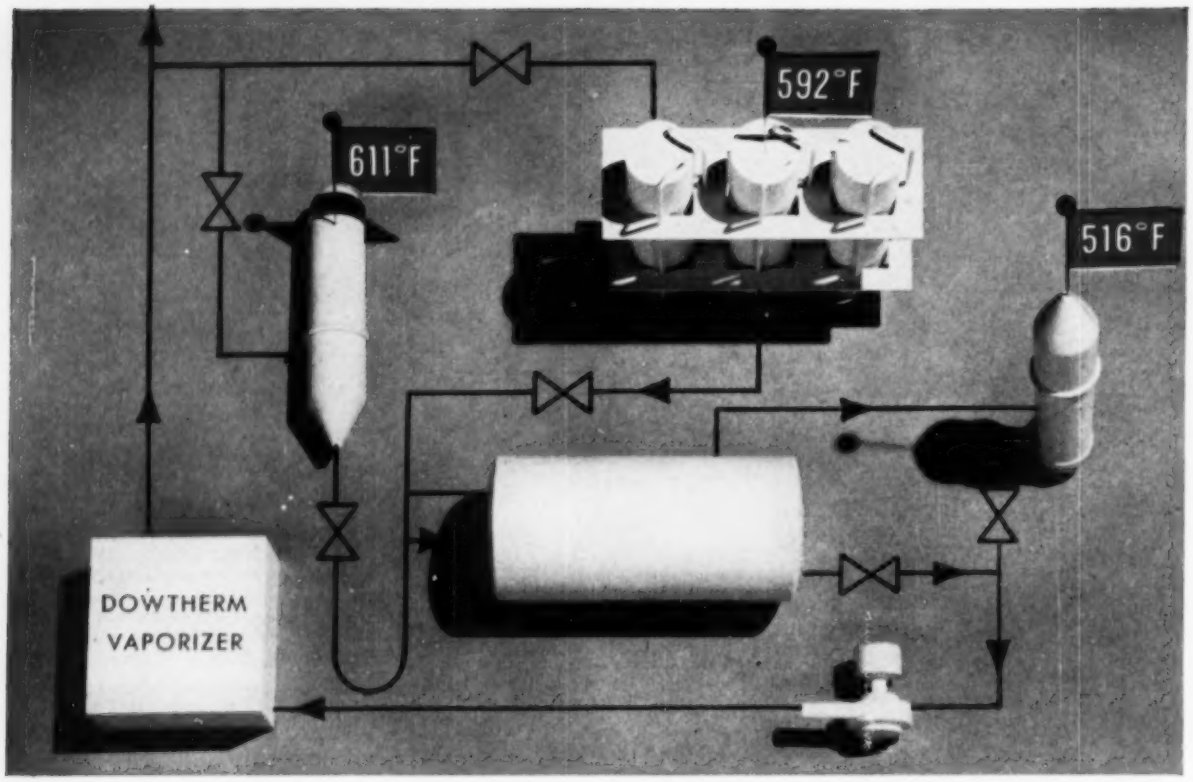
Through more accurate measurement, this system helps to produce greater quality and uniformity in resin formulas. It saves time and labor, too, by giving a continuing inventory for cost-accounting purposes.

Electronic weighing systems offer endless opportunities for measuring materials in storage, or in motion. Your nearby Honeywell engineer will be glad to discuss the possibilities in your own plant's operations . . . and he's as near as your phone.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, Wayne and Windrim Avenues, Philadelphia 44, Pa.

● **REFERENCE DATA:** Write for Data Sheet No. 10.18-1a, "Unit Measuring Systems with Baldwin Electric Strain Gages," and for Catalog No. 1531, "*ElectroniK* Controllers."

MINNEAPOLIS
Honeywell
BROWN INSTRUMENTS
First in Controls



PINPOINT TEMPERATURE CONTROL made possible by DOWTHERM

Dowtherm®, the modern heat transfer medium, requires but a *single vaporizer* to serve *several consuming points* with different temperatures at just the desired degree. Simple pressure regulation gives the temperature you want, where you want it, for pinpoint control that can be maintained correct to a fraction of a degree.

A liquid material used as a vapor heating medium in an entirely closed system, Dowtherm operates at high temperature, low pressure, and extends the advantages of steam-type heating to a much higher range of temperatures. If your process cycle requires alternate heating *and cooling*, however, Dowtherm liquids serve as a coolant in the same equipment.

Dowtherm contains no minerals—therefore causes no costly scaling and forced shut-downs of vaporizer or processing equipment.

Many process industries have utilized Dowtherm to develop new products or improve old products—through better production control. Whether you're planning a new plant or expanding present facilities, you'll find the Dowtherm bulletin helpful. Write for your free copy, to THE DOW CHEMICAL COMPANY, Midland, Michigan, Dept. DO 878A.

you can depend on DOW CHEMICALS

DOW

YOU CAN PUMP IN CONTROLLED VOLUME

HYDROCHLORIC ACID... ALL CONCENTRATIONS

CHLORINATED HYDROCARBONS

CORROSIVE METALLIC SALT SOLUTIONS

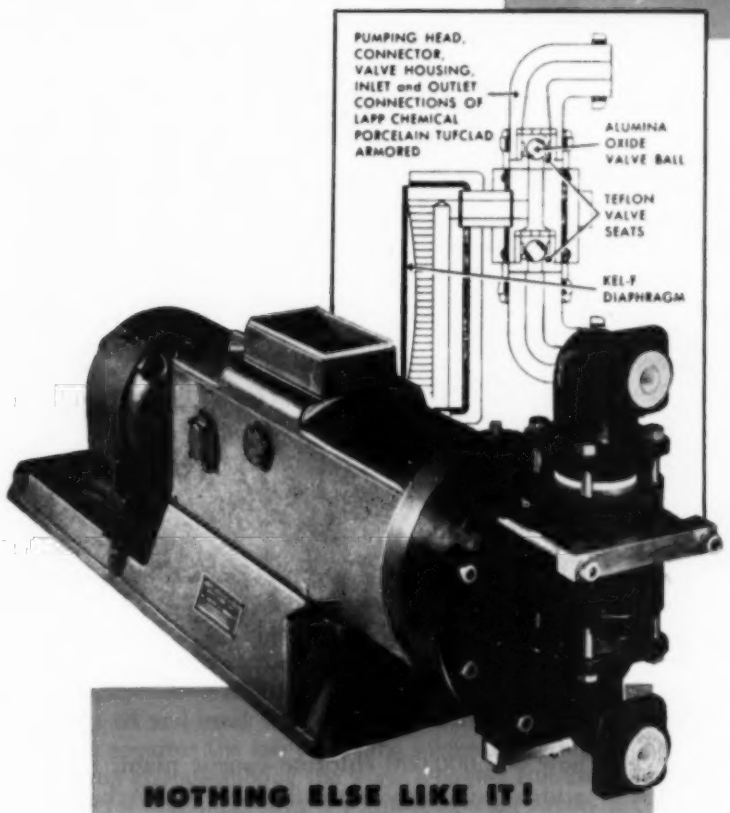
DILUTE ACIDS

MIXED ACIDS

WITH

Lapp PULSAFEEDER

COMPLETELY NON-METALLIC CONSTRUCTION


PUMPING HEAD, CONNECTOR, VALVE HOUSING, INLET and OUTLET CONNECTIONS OF LAPP CHEMICAL PORCELAIN TUFCLAD ARMORED
ALUMINA OXIDE VALVE BALL
TEFLON VALVE SEATS
KEL-F DIAPHRAGM

Solid Lapp Chemical Porcelain, combined with parts of alumina ceramic, teflon and Kel-F plastics, is used for the liquid end of this model of Lapp Pulsafeeder. All parts which can come in contact with liquid being pumped are non-metallic, chemically inert. Thus, positive-displacement metered pumping of "hard-to-handle" corrosive chemicals is made certain and permanently trouble-free.

WRITE FOR BULLETIN 300

with typical applications, flow charts, description and specifications of models of various capacities and constructions. Inquiry Data Sheet included from which we can make specific engineering recommendation for your processing requirement. Write Lapp Insulator Co., Inc., Process Equipment Division, 400 Wilson Street, Le Roy, New York.

NOTHING ELSE LIKE IT!

Lapp Pulsafeeder is the combination piston-diaphragm pump for controlled-volume pumping of fluids. Reciprocating piston action provides positive displacement. But the piston pumps only an hydraulic medium, working against a diaphragm. A flexing, balanced partition, the diaphragm isolates chemical being pumped from working pump parts —eliminates need for stuffing box or running seal. Pumping speed is constant; variable flow results from variation in piston-stroke length—controlled by manual hand-wheel, or, in Auto-Pneumatic models, by instrument air pressure responding to any instrument-measurable processing variable.

TO $12,000,000 NEW CHLORINE-CAUSTIC CAPACITY!

MONTAGUE, MICHIGAN is the scene of this sparkling Hooker Cell installation by Hooker Electrochemical Company. Part of a new $12,000,000 chlorine-caustic plant, it adds significantly to the demand for "Acheson" graphite anodes in this vital process.

The term "Acheson" is a registered trade-mark of Union Carbide and Carbon Corporation

NATIONAL CARBON COMPANY

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District Sales Offices: Atlanta, Chicago, Dallas, Kansas City, New York, Pittsburgh, San Francisco

IN CANADA: Union Carbide Canada Limited, Toronto

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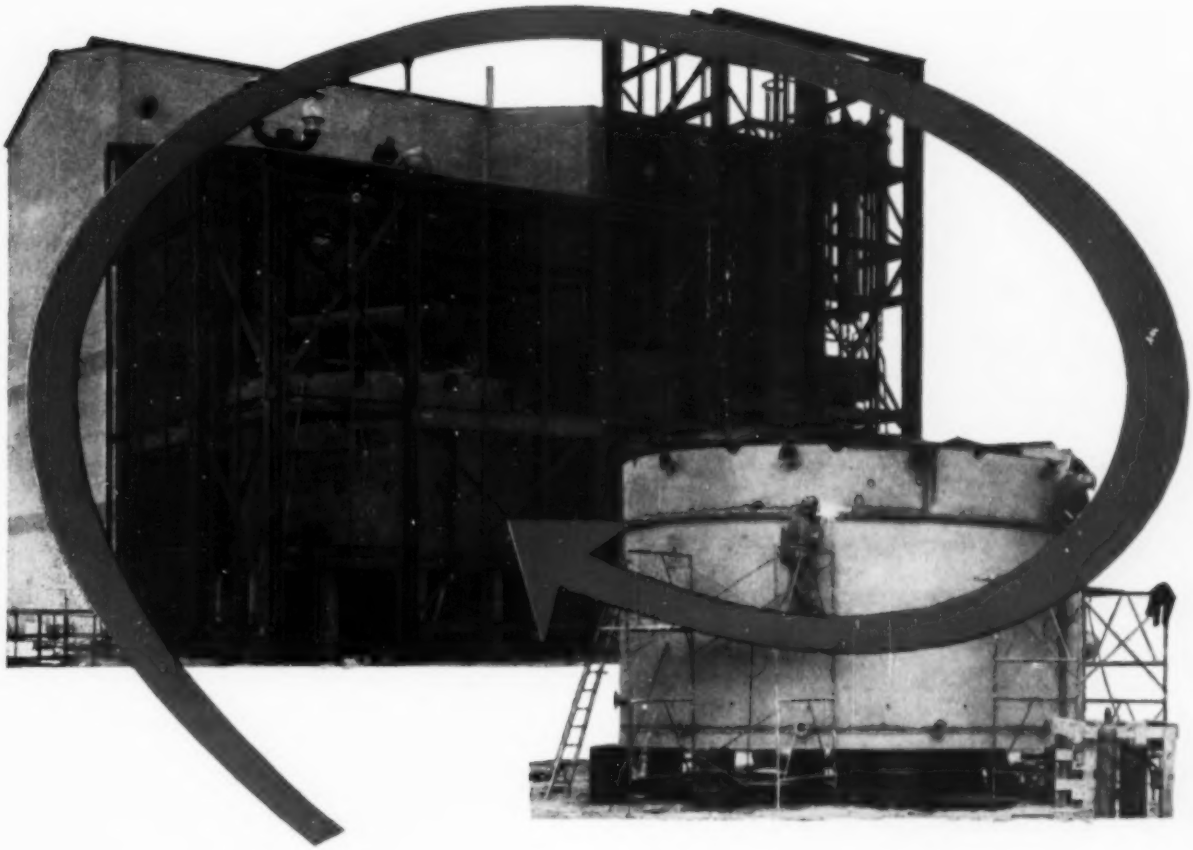

BLAW-KNOX puts the skids under a hazardous project to increase Honeymead's capacity

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Honeymead is a fast-growing Minnesota producer of soy oil and meal. Extraction of oil from soybean flakes requires the use of hexane solvent. Cutting, welding and assembling the world's largest Rotocel extractor and integrating it with the existing vapor-filled equipment without interrupting operations necessitated a unique engineering approach.

Blaw-Knox fabricated the 500 ton per day Rotocel, 24 feet in diameter, and distillation equipment four stories in height at a safe distance. As each unit was completed, it was lowered onto cribbing and skidded carefully into place.

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NOTED AND QUOTED

(*Continued from page* 14)

Education—A Continuing Process for The Engineer

As engineering became more complex and a higher value was placed on life, succeeding generations created the safety engineer. Today he is responsible for the extremely low industrial hazard rate. It was his work that contributed in a large measure to our instrumentation. Today we run many of our machines by instruments that are as easy to read as a clock. One knows whether he can safely approach a machine or device. All this is a remarkable tribute to engineering as our country progresses in the atomic age.

With materials in use today that create and hold powers of deadly radiation, we find that these can be safely handled although their deadly effects are known. Insurance companies do not even consider radiation an industrial hazard when it is properly handled and instrumentation is complete.

There are available today instruments which, when placed in an area having dangerous or toxic gases, will set up warnings when such areas become unsafe. Where radiation is concerned, badges of synthetic film have been developed that, if radiation is apparent, will immediately discolor and warn the wearer before he can be exposed or physically harmed.

In these United States, we value health very highly in this breakneck pace of our industrialization and take every precaution to protect human life from danger.

The question frequently asked by engineering graduates is how much further should they continue for advanced degrees, and that is what the foregoing is intended to convey. With the rapid increase in engineering potential, if you have the ability for it, you should continue to pursue your education and acquire additional degrees.

At one time engineering courses were relatively short, but today science has progressed so far and has so many facets that it is necessary for the young engineer to learn more and more. Many educational aids have been introduced in an effort to shorten the length of time required but most educators agree that engineering today is so vast and complex that it is difficult to impart the necessary education in less than five years.

In this complex and complicated civilization, it is also necessary to have a great deal of general knowledge in the cultural subjects so that one doesn't

(*Continued on page* 32)

Catalysts

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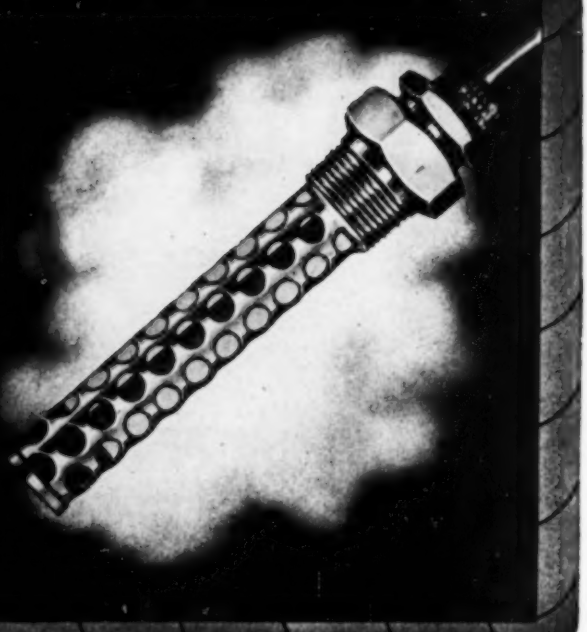

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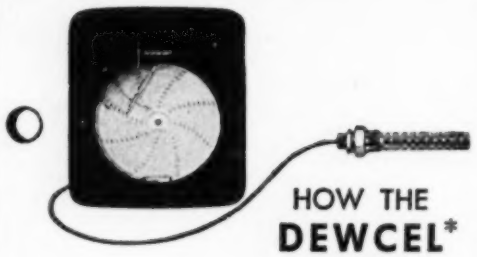

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The Dewcel element is a thermometer bulb (liquid-filled or electric-resistance type) jacketed with lithium-chloride-impregnated woven glass tape. Over this are wound two spaced gold or silver wires connected to an AC source. The lithium chloride absorbs moisture, allowing current to flow, generating heat, and raising the temperature. Equilibrium temperature is reached when vapor-pressure of the moist salt exactly balances that of the surrounding air or gas. The System translates this temperature into direct readings of dew point.

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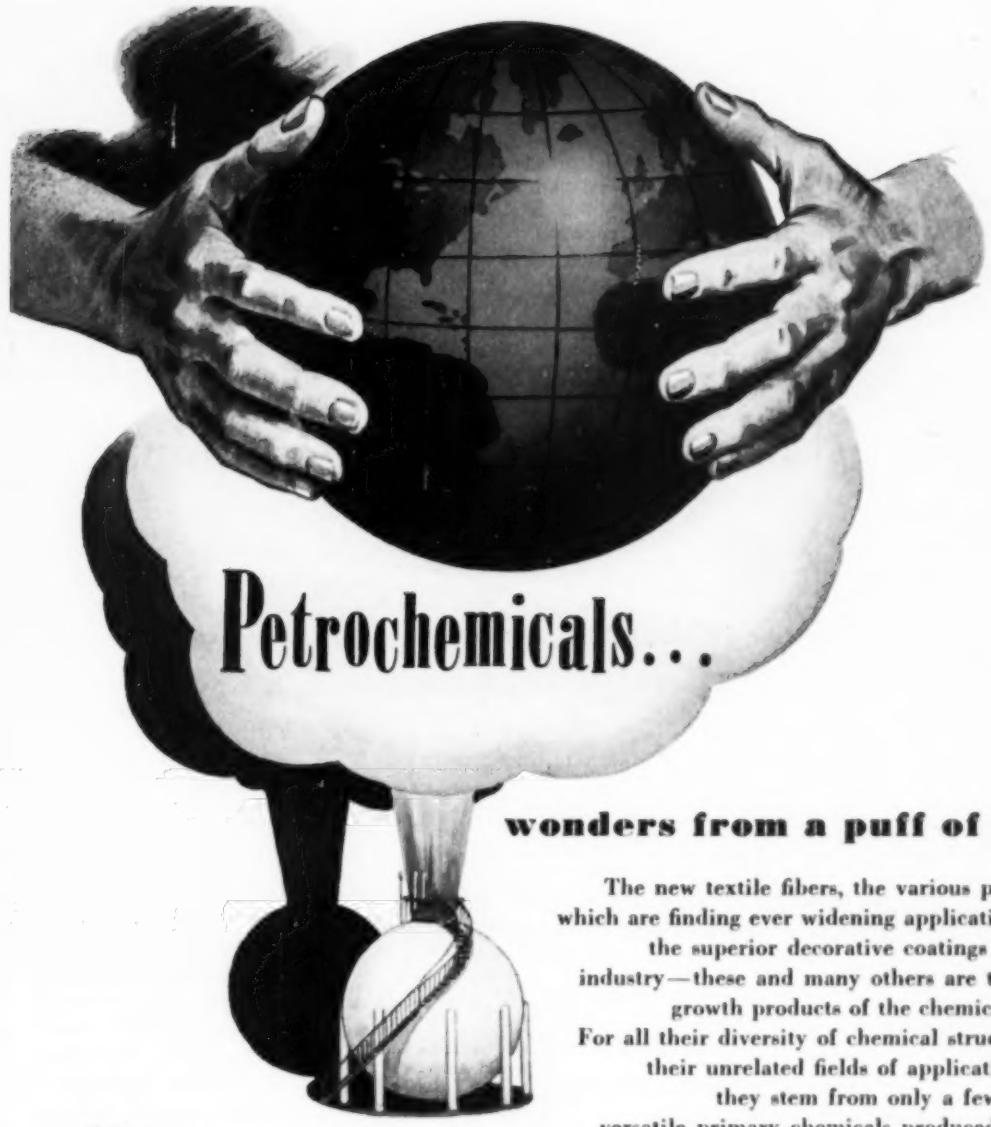

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NOTED AND QUOTED

(Continued from page 28)

become warped in his thinking but instead has a fuller and broader knowledge of the world about him in relation to his own field and his fellow man. Engineers must be educated to become real men with a sense of fairness, decency and honesty as part of their makeup.

Arthur J. Schmitt
Age of Opportunity
industrial science and engineering

Things of The Mind in The Ascendancy

Not in many decades has the role of the artist, the philosopher or the scientist been so highly regarded in this country as it is today. It is now possible for an American business man or statesman to profess, without public mistrust, interest in cultural matters . . . without question or suspicion; indeed, with approval. . . .

A similar rejection of the idea that we are sitting precariously on a mounting wave of anti-intellectualism is made by Jacques Barzun in . . . "America's Passion for Culture" which appeared in *Harper's* for March. As he observes, the "line" in the colleges has changed; "it is no longer smart to be anti-intellectual. . . ." He notes that "the institutes of technology are more and more introducing courses in the humanities, so that in a few years the word engineer will no longer be a polite way of saying Philistine."

Speaking of Books
J. Donald Adams
New York Times

It's Industry That Pays

The cost of fundamental research, whether direct or indirect, is really borne by industry. By far, the major proportion of all college and foundation money has come either directly or indirectly from industrial profits. . . The government money also comes from industry, and the government developments go back to industry. . . . The changing emphasis in our economy in the direction of more and more government money has led us into a fallacy of thought that the government is supporting large amounts of fundamental research. In reality, this government research is aimed at more specific goals than industrial research and is invariably administered by government bureaus with a shorter over-all planning.

Lt. Gen. Leslie R. Groves
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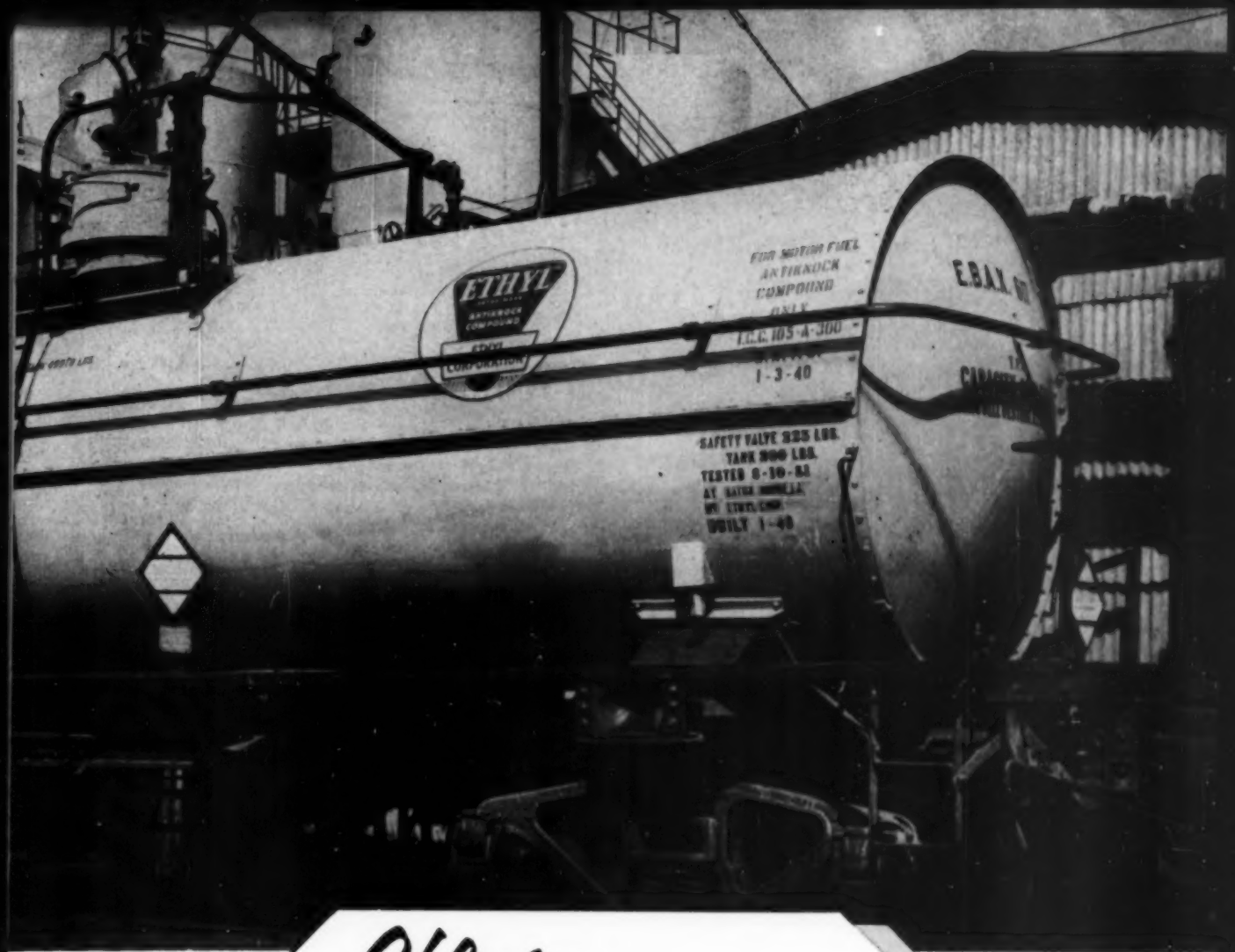

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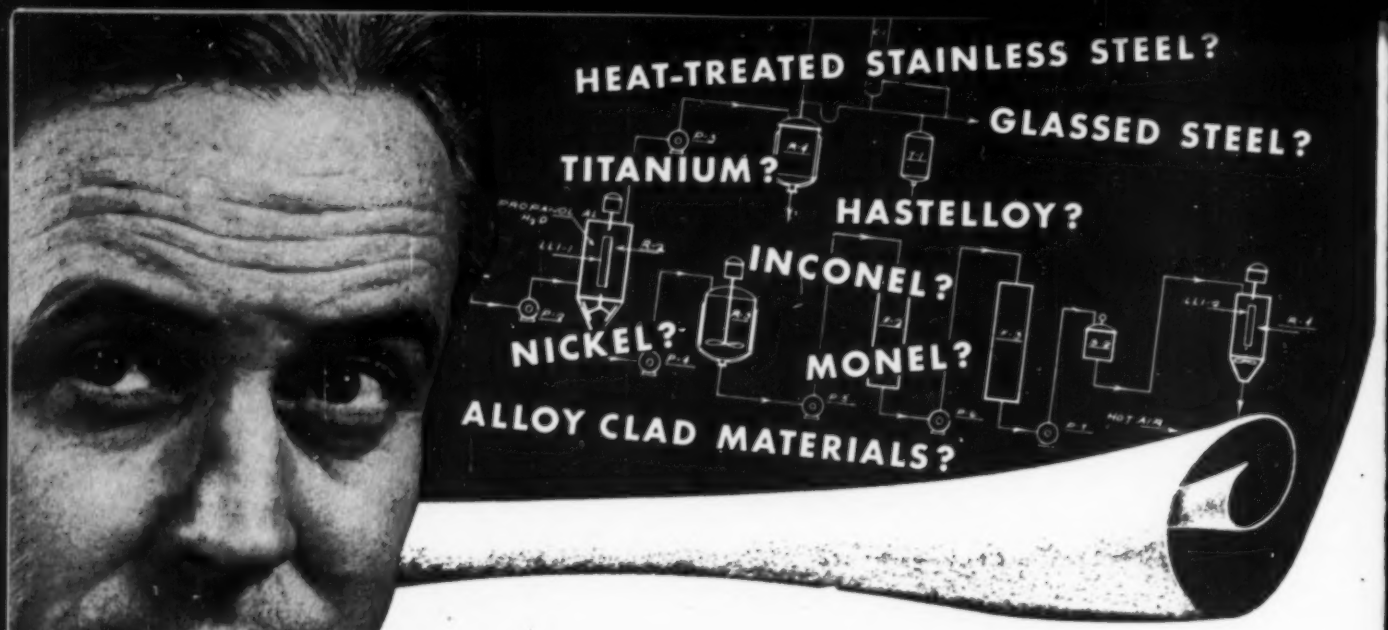

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Try us on your requirements —whether they involve a complete process assembly or individual units. Bulletin 902-B-5 explains how you can use Pfaudler services and facilities to best advantage in minimizing corrosion costs as well as getting better yields. Send for it today.

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Opinion and comment

$ALARIE$ AND ENGINEER$

Nothing interests us like ourselves, especially a comparison of our salary to the salaries of other engineers. Salary surveys continue to appear, ranging from the personal search of the want-ad columns and rough comparisons of the amounts offered clerks, deep sea divers, barbers and laborers with the current salaries offered engineers, to the complicated investigations of the professional engineering organizations. The newspaper search often causes deep concern. Engineers seem to be in no more favorable position than drivers of garbage trucks, and based on such quick surveys, premonitions of disaster for the whole profession are easy to come by.

For chemical engineers the A.I.Ch.E. has, in the past, relied on its own studies. The most recent survey of the whole membership was published in C.E.P. last July and, in summary, in January of this year. The results were not at all discouraging. As a matter of fact the curves showed on the whole steady increases, and the picture for A.I.Ch.E. members was promising.

But now the Engineers Joint Council has published a study of engineers' salaries which requires explanation to Institute members, and caution must be used if the figures are to mean anything. Titled "Professional Income of Engineers," it is the work of a Special Surveys Committee and is an adjunct to a survey on demand of engineers in industry. Data were collected from companies employing engineers, not from individual engineers, and in the report no differentiation is made in the kind of engineers on whom the company supplied data.

Direct comparison of the A.I.Ch.E. and E.J.C. data is difficult; nevertheless in the early professional period, up to ten years out of school, the E.J.C. study follows closely the experience of A.I.Ch.E. members. But after the ten years are up, a peculiar thing happens. The salaries of the engineers in the E.J.C. survey, reported by the companies, begin to level off and soon hit a plateau, and in comparison with those of Institute members sink lower and lower, ending up below the A.I.Ch.E. third quartile. The E.J.C. survey shows that an engineer out of school since 1930 is earning $8,780. The A.I.Ch.E. shows him earning close to $14,000. The break seems to come at the ten-year experience level—graduates of 1942. Both surveys show them earning (in late 1952 and early 1953) a median $7,200. From there on, however, Institute figures show a steadily increasing advantage. There are several explanations for this difference.

First and important is the fact that E.J.C. obtained data on all engineers employed by the chemical companies reporting. The companies were asked for information on any man having an engineering degree. There was confusion as to the meaning of this requirement. Some companies interpreted the request to be for data on those still doing engineering work. Others gave the data on everyone (including executives) having an engineering degree. Second, the survey tapped only a limited sample. Out of the seventeen companies only one could be considered as major, in that it reported on 1,000 engineers. Finally the reporting sample of companies from the chemical field was not particularly representative.

Those who made the study for E.J.C. admit these shortcomings and claim only that this survey is valuable in that it reports salaries of *all* engineers and is not "limited by being restricted, for the most part, to members of professional societies." Therein is probably the answer for the vast difference in salary experience after the ten-year level.

Other surveys have revealed this same fact—members of a professional society command higher salaries. Many assumptions can be made as to why, but perhaps it is all summed up by saying that the man who joins a professional society is the man who looks upon engineering as a profession. The man who does not join his professional society looks upon engineering as a job, as a way of earning a living. As so often in life, devotion to a principle brings added things.

Professional membership must have its influence on the work, the mental attitude, the information quotient, the conversational interests, and the pride of everyone who joins. And over the years, this might just make the difference.

THE ATOMIC ENERGY ACT OF 1954

On April 15 Senator Hickenlooper introduced S. 3323 to the Senate, and Joint Committee Chairman Cole introduced H.R. 8862 to the House, thereby opening what may well be one of this country's most important vistas of technical progress. These are the long awaited bills to amend the Atomic Energy Act of 1946, and the new law, if indeed it becomes law, opens on the positive note that "the development, use and control of Atomic Energy shall be directed so as to promote world peace, improve the general welfare, increase the standard of living, and foster our system of private enterprise."

The bills must go through public hearings and congressional debate before they become law, but the changes that have been suggested are of some importance to all in industry, especially the chemical process industry.

The new act would give the President broad powers to transmit atomic data to our allies in N.A.T.O.; it would provide for licensing industry in the nuclear field; the materials used in fusion would be brought under the province of the Atomic Energy Commission by being declared "special material," and restrictions would be placed on them similar to those now existing with regard to fissionable materials; it would provide for patents to be held in the development of nuclear energy for peaceable uses; and the rights to uranium discovered on public lands would no longer be reserved to the government.

There are many more interesting provisions, and perhaps in this brief review important points have been skipped. However in our opinion, engineers in the chemical field, both in the executive and in the development, design and operating groups, ought to become familiar with the provisions of the proposed law. Here is an opportunity for representatives of the chemical process industries to provide the public with a technical interpretation of an important legislative matter. We expect the hearings to kick up quite a few hot arguments, and calm discussion of all points by informed chemical engineers could be an important service to the country.

F.J.V.A.

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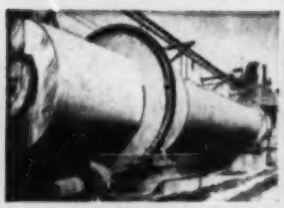

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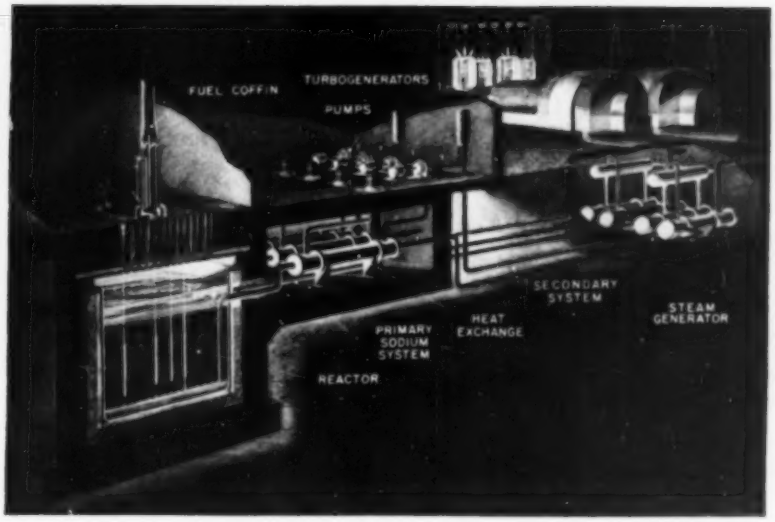


Nuclear Engineering

a chemical engineering review

BY THE EDITORS OF
CHEMICAL ENGINEERING PROGRESS

Engineering is now on the threshold of the nuclear age—an age in which much of our power will be generated by the heat from neutrons crashing their way through obstacle-barriers of carbon and heavy-hydrogen atoms. From the radiations given off by artificially unstabilized atomic nuclei will come more uses and products than can readily be imagined beyond our present areas of exploration in food sterilization, synthesis-initiation, tagged-atom tracing, and medicine. To enter the new age to an important degree industrially will, however, require a tremendous and ingenious engineering effort, much of which will have to come from the chemical engineer—not only because of his proved versatility, but also because so many of the problems now standing in the way of progress are basically similar in nature and scale to those he has solved in other fields. For these new responsibilities, the chemical engineer will need to acquire a working knowledge of the fissioning atom and its effects and a mastery of the new technique of remote manipulation and control. This article reviews a few of the broader technical and economic factors behind the accelerating program and endeavors to present a simple picture of the basic energy forces offering such fabulous promise and yet creating such great challenges.

What Is Nuclear Engineering?

Nuclear engineering has been defined as basically chemical engineering, with the addition of an amount of mathematics and nuclear physics about equal to the amount of chemistry in the Ch.E. curriculum. This appears however to summarize the ideal training of all-versatile persons, rather than to take into account the actual situation that a great many chemical engineers already specialized within the framework of their profession will be taking responsible parts in a field in which nuclear physicists and others are already present and making available their specialized knowledge and services.

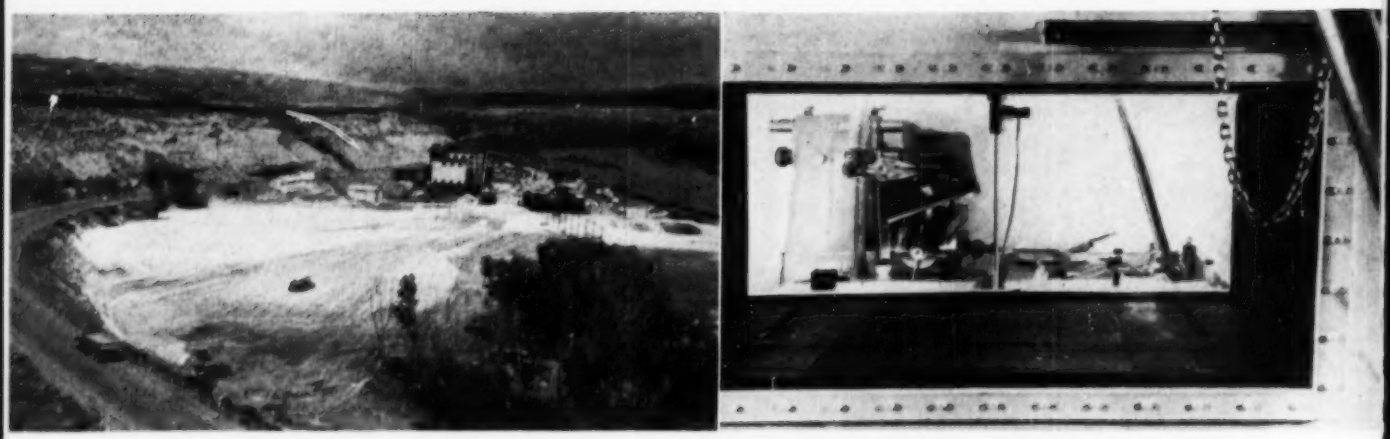
Nuclear engineering embraces the *nuclear aspects* of

ore processing
fuel production
fuel "burning"
spent-fuel regeneration
heat removal
radioactive initiation of syntheses
radiochemical production, and
radioactive wastes disposal.

All of these are recognized as familiar interests and activities of chemical engineers, except for the *nuclear aspects.*

That these *nuclear aspects* can impose great departures from conventional procedures is illustrated by safety considerations, which call for Geiger counters and extensive personnel protective paraphernalia. Then, too, the very design of plants, to provide for safety and also to make infrequent but possible any adjustments and repairs, has to be on quite a different basis. Equipment has to be designed as if it is to last a century —and then be placed within canyons of shielding materials. Access must be assured to the giant arms extending from an overhead crane, which gently though powerfully manage to position, unbolt, lift, transfer, deposit, and sometimes even disassemble, rebuild and replace equipment in caverns where no man could remain very long and live.

In the present status of industrial nuclear operations, a sufficient number of primary technical objectives have been achieved to permit a most optimistic prediction as to the success and importance of the ultimate objectives (power, etc.). The array of devices and special designs that have been employed is, however, so complex, cumbersome and expensive as to preclude any immediately satisfactory demonstration of *economic* achievement. It is felt with the entry of private initiative into the field, together with the simplifying and streamling talents of the chemical engineer, that the practical realizations may be speeded with widespread benefits.



▲ Fig. 2. The oldest operating uranium ore mill in the U. S., at Rifle, Colo. (*Courtesy U. S. Vanadium Co., a division of Union Carbide.*)

Nuclear Power

The most emphasized immediate goal in the nuclear field is power production. There are several reasons why this offers so much incentive, even though present "conventional" fuels are providing power at reasonably low cost. At the present time, various industrial regions differ considerably in their power costs, due to the expense of transporting coal or oil. The savings to be expected in shipping *one pound* of nuclear fuel in comparison to 2,600,000 pounds of coal (the two are theoretically about equal in heat content) are highly stimulating to such regions as New England, the British Isles, and many others throughout the world.

Even this basis of favorable comparison has been improved upon by the advent of "atomic breeding," through which the power-producing reactor may be made to produce more fissionable fuel than it consumes. When such a system becomes a working reality—and it does seem promising—a tremendous potential will exist for making fuel costs (and make-up *quantities*) virtually insignificant. To achieve economical nuclear power by this or any other type of reactor means adding a chemical processing plant to the power reactor, which may be practical if chemical engineering can provide the solutions to the many problems which this creates.

The World Fuel Supply Factor

Another important consideration in deciding whether to build nuclear power plants is the long range outlook for nuclear as well as conventional, or "fossil," fuels (coal, oil, gas, etc.). In 1949 the A.E.C. employed a consulting engineer, Palmer Putnam, to study and report on the future world demands for power and the availabilities of fuels ("Energy in the Future," Van Nostrand, N. Y., 1953). He estimated that the peak production of fossil fuels recoverable at economical cost may be reached within the next fifty years but that associated increases in real costs will be significant before 1975. Thus the rising costs of fossil fuels compared with the decreasing nuclear fuel costs (to be expected as fuel processing technology advances) may be a determining factor in favor of the latter. He further estimates the energy reserves of low cost nuclear fuels to be twenty times as abundant as those of reserves of low cost fossil fuels.

Present Nuclear Fuel Sources

The richest ore deposits are in Canada, Belgian Congo and Czechoslovakia (for uranium) and Brazil and India (for thorium). Domestic nuclear power is not, however, necessarily dependent on these rich sources, as modern chemical engineering processing techniques have been instrumental in producing with satisfactory economics a good flow of uranium from mines in the Colorado Plateau, from shales throughout the West, and, as a by-product, from the Florida phosphate rock fertilizer operations.

The Nuclear Fuels

There are only three. They are U^{235} (uranium isotope having an atomic weight of 235) and Pu^{239} (plutonium) derived from natural uranium, and U^{233} derived from natural thorium. Of these only U^{235} actually occurs in nature and then only to the extent of one part in 140 of pure natural uranium. The other 139 parts are U^{238}, which prior to transmutation is not fissionable and not thereby directly usable as a fuel. Pu^{239} and U^{233} have to be produced by man-made transmutation devices, which employ a process of depositing a neutron in the nucleus of an ordinary uranium or thorium atom, with subsequent radioactive decay to the new element, Pu^{239} or U^{233}, respectively.

U^{235} may be used in the form of "natural" uranium, or enriched uranium fuel. Enriched fuels are produced by removing varying amounts of U^{238} from the natural uranium by physical means, such as the gaseous diffusion process, and thus enriching the residue in U^{235}. The greater this enrichment, the smaller can be the size of the reactor and the less critical is the choice of various other reactor materials.

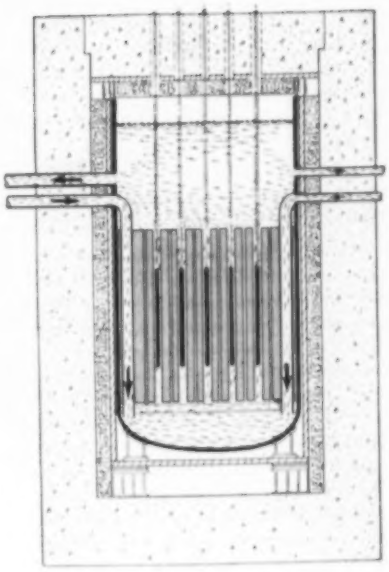
Pu^{239} and U^{233}, on the other hand, can be separated in essentially pure form by chemical processes, although not without great difficulty. Obviously the availability of these substances in undiluted form offers much greater flexibility in advanced types of reactors. For example, in various types of breeder reactors, the "core" (in which the nuclear chain reaction takes place) may consist of highly enriched U^{235}, Pu^{239} or U^{233}, surrounded by a "blanket" of excess-neutron-absorbing natural uranium or thorium, in which will form additional fissionable material (Pu^{239} in a uranium blanket, U^{233} in a thorium blanket).

Fuel Production

Pure uranium and thorium metals had not been produced prior to World War II, even in small quantities, and so a great deal had to be learned. Crude oxide production from the ores, though previously possible and not complicated, benefitted materially from the application of modern chemical engineering techniques. To produce even highly purified oxides, however, required development of an advanced solvent extraction technique employing ether as a selective solvent to separate uranium from rare earths. The reduction of the oxides of uranium and thorium to metallic form has entailed great problems but these have been somewhat simplified to the degree that production is routine. Pu^{239} and U^{233} are particularly difficult to produce in metal form and to fabricate, because of their radioactivity.

◄ Fig. 3. A machine tool behind 3-ft. thick pane of radiation-absorbing glass. Note "hand" of remote operating mechanism. (*Courtesy Argonne National Laboratory.*)

Fig. 4. Cross section of one type of reactor ► core. Uranium fuel rods are suspended in liquid sodium coolant. Cross-hatching indicates graphite moderator. (*Courtesy North American Aviation, Inc.*)



If the need for metallic fuels could be eliminated completely, however, both fuel production and reprocessing of "spent" fuel (which has been slowed in effectiveness through the formation of by-products) could be a great deal simpler and lower in cost. One type of reactor, the "homogeneous," uses liquid fuel (a solution of uranyl nitrate in water) and offers considerable promise of success.

How Fuels "Burn"

Natural uranium metal is safe to handle, as far as its slight radioactivity is concerned. When bars of this metal are, however, laid at carefully spaced positions between blocks of graphite (moderator) or between volumes of water, and just the right quantity of metal is so positioned, then a "chain reaction" begins. The temperature of the assembly rises quickly and soon energy is being released in enormous quantities. By pushing in or pulling out control rods of neutron-absorbing material, the activity level of the assembly, called a "pile," may be regulated. Such a system functions with natural uranium metal. A pile differs from an atom bomb by manner and speed of introduction of a critical quantity of fissionable material into a critical space pattern. In the bomb, the critical quantity of material is blown into the critical space within a fraction of a second, and the chain reaction goes to completion in a very short time. For this, highly purified fissionable material is used.

The nuclear phenomenon which takes place is one of the great wonders of science. The U^{235} in natural uranium is capable of being split or fissioned by interaction with *slow* neutrons. In this operation tremendous energies are imparted to the other neutrons which are released. Each of these fission neutrons leaves at such an enormously high speed that it plows its way past all other nearby uranium atoms and escapes. In the lattice structure described earlier, such neutrons are made to pass through obstacle-courses (moderators) of lightweight atoms, such as carbon atoms of graphite, with which they collide many times until their speeds are slowed to such a point that when entering the next adjacent body of uranium, they will with great statistical frequency lodge themselves in the nucleus of U^{235} atoms. The arrival of each of these, however, creates a condition of instability in the host nucleus which finally causes it to fission, releasing an average of 2.5 neutrons at high velocity.

The high velocity neutrons are called "fast" neutrons. The slow ones, after having passed through the moderator, are called "thermal" neutrons. The latter name is derived from their having been slowed in the collision operation to the same speed as that of their carbon dancing partners. Another way to state this is that as the fast neutrons are slowed, they impart increased vibrational energy to the carbon atoms, which is the manner in which heat is generated within the nuclear reactor. Since 2.5 neutrons are produced from a single thermal neutron, and only one of the 2.5 is required to maintain the fission reaction, 1.5 neutrons are theoretically available for fuel production in a breeder reactor in which the core is wrapped in a blanket, as described earlier.

The Nuclear Reactor—and the Problems of Removing Its Heat

Many types of reactors have been devised; all share basic principles. Some use solid fuels; others liquids. Most disperse the nuclear fuel within a body of moderator for production of thermal neutrons. With the homogeneous reactor, which employs uranyl nitrate in water, the latter acts as moderator. However, water is parasitic of neutrons and disturbs the precarious neutron balance unless enriched fuel is used and a "reflector" of graphite or water is placed in such a manner as to turn back and thus conserve any stray neutrons.

All reactors must have cooling systems, which in the case of power reactors are heat-gathering systems. Some employ metallic sodium and operate at temperatures above its melting point. Others use water, some maintaining the water under pressure to keep it liquid, and others allowing it to boil for generation of steam. All heat-removing media leaving the core of the reactor are highly radioactive, and in the past they have been held in isolation from the steam turbine equipment through the interposition of one or more stages of intermediate heat exchangers. Such exchangers have to be securely leak-proof to prevent transfer of radioactive material, and in addition when sodium is used, to prevent explosive interaction with water.

Another problem arises from water subjected to radiation; it has a tendency to decompose into hydrogen and oxygen, which must be recombined by burning, to avoid explosion hazards.

Fuel Contamination

When a graphite-uranium reactor is charged with metallic uranium rods and the fission reaction is controlled at an efficient level, heat is produced at a constant rate for a time. Ultimately, heat production begins falling off and eventually becomes almost nil. Yet analysis of the fuel remaining in the reactor would show that only a few tenths of a per cent of the original material has been used. What has happened is that neutron-absorbing by-products of the fission reaction have been formed to such a degree as to stifle the chain reaction.

At such a point either the spent fuel must be replaced with new, which is expensive and wasteful, or the by-products must be removed so that the fuel will once again function. Such spent fuel "cleanup" has been cited as a problem area in which chemical engineering is likely to have its greatest effect in helping to make economic nuclear power generation possible. Costs incurred in fuel reprocessing are of highest consequence.

As development work now stands, solvent extraction has been described as one of the best means of accomplishing the separation, using organic solvents as selective agents. One advantage of this process is that it lends itself to a continuous recycle of fuel with respect to a homogeneous reactor. Other processes employ ion exchange (which requires regeneration) and carrier precipitation (which has a time element involved that makes it more readily a batch operation).

One of the greatest problems of spent-fuel regeneration is its intense radioactivity as it leaves the reactor. If it can be stored for months, this can be reduced materially through decay of

shorter-life fission products. For a continuous-operating system, however, the problem of maintenance must be met through the use of techniques similar to those in the following example.

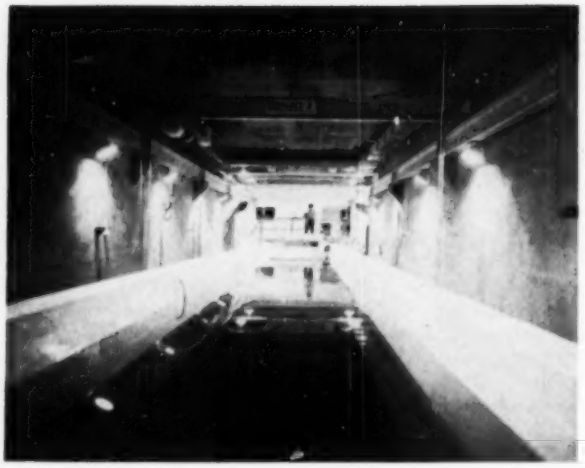


Fig. 5. Canal behind materials-testing reactor. Though the purpose is to receive and store cans of irradiated materials, it is illustrative of the "canyons" referred to in the text. (Courtesy A.E.C.)

What Chemical Separation Plants Entail

One of the semi-annual reports of the A.E.C. (8th, July, 1950) contains the following description: All processing equipment which in an ordinary chemical plant might be lightly enclosed or placed in the open must be housed in massive concrete trenches and cells. The whole structure must be designed for high efficiency ventilation, and the ventilating system must be supplemented by elaborate filtration equipment to prevent release of radioactive materials to the outer air. The lines carrying liquid and solid wastes to disposal points must be as strong and trouble free as it is possible to make them. In fact, the entire plant must be constructed as though it were expected to operate for a hundred years, with a reliability far beyond anything ever considered practical in the chemical industry generally. Yet all machinery needs repair occasionally, and remotely controlled maintenance equipment must be provided along with the operating equipment. To begin with, no man could safely go into the region where the trouble lies. It is necessary that the piece of equipment containing the faulty unit be detached and removed from its normal position and placed in a position within the sealed canyon where men can work and still be shielded from the radiations emanating from the process area. A work crew, properly clothed and protected, makes a quick trip into the canyon to lay down and tape heavy paper on the floor at a chosen spot, so that the piece of equipment, when deposited, will not contaminate the concrete surface. Then the crane in the canyon goes into operation.

This remote-control crane is able to reach any point in the huge canyon area, and to detach and lift out any designated piece of equipment from amidst a maze of machinery. Also, it lifts, gently and accurately, the protective shielding needed to safeguard the workers—blocks of concrete weighing up to 36 tons.

When the crane has finished, the piece of equipment that is to be worked on is lying in the prepared spot; the area around it is shielded from the other processing equipment; and fences have been erected to prevent personnel from moving into danger areas. The piece of equipment itself, however, is a radiation source; being highly contaminated with process solutions, it is broadcasting powerful gamma rays in all directions.

The mechanics who are to repair it do their work only for calculated times and at calculated distances. If the job is not a familiar one, it will be rehearsed in advance. Sometimes even special tools have to be devised.

As men leave the canyon, it may be assumed that they are potentially contaminated from head to foot. So they go through a standard change room procedure common to many present day process plants handling toxic materials. There is one step added, however, and that is the checking of themselves to determine the presence of radiation.

The techniques described above, from the A.E.C. report, are only part of the technology which will become commonplace in the nuclear age. Chemical engineers will not only have to live with these procedures, but continue to develop and enlarge upon them.

Waste Disposal

Another part of the nuclear puzzle yet to be satisfactorily resolved is the disposing of radioactive wastes, either gaseous or solid. While most methods employed to date have provided adequate assurance, these have not established a basis for disposing of the increased quantities expected in the future. One of the problems entails concentration, and one of the recent studies has shown algae to be capable of selectively accomplishing this, following which they are removed by rotary filters.

Developments

In addition to development of chemical separation techniques, one of the areas of intense activity is in the field of nuclear reactors. A.E.C. Member Smyth, in a banquet address during the recent Washington, D. C., national A.I.Ch.E. meeting, announced (see digest of his remarks, p. 35 of this issue) the decision on the part of the government to proceed with the building of four more experimental reactors, one of which will be a "water boiler" type. This is an extremely important experiment as it, if successful, will achieve the passage of steam generated in the core of the reactor directly through a turbine, without the use of intermediate heat exchangers.

Smyth also announced a large homogeneous reactor (also see paper by Beall and Winters, p. 256 of this issue) to be built and made to generate electric power. It will be noted that in the two projects cited, the direct generation of steam and continuous reprocessing of spent fuel are primary objectives.

There are many other developments under way, having to do with nuclear power, food sterilization, organic syntheses activation and other subjects—some aspects of which will be described for the first time in declassified papers to be presented at the Ann Arbor meeting in June (see Preview: Ann Arbor Meeting, p. 37 of this issue). Some of these papers are contained elsewhere in this issue of C.E.P.; others will appear in C.E.P. Symposium Series volumes. One of these will be available at the Ann Arbor meeting; others will appear subsequently.

The Chemical Engineering Future

To a degree, the rate at which the application of chemical engineering techniques can be made to achieve better, more economical nuclear processes depends on congressional revision of the Atomic Energy Act, particularly along the lines requested by the Administration. At present, dissemination of information, much of a chemical engineering nature, is drastically curtailed. Furthermore, it is presently not permissible for a private group to own fissionable material, nor is it possible to obtain the protection of the patent system for private discoveries and inventions. As this is changed through enactment of revising legislation, it is expected that private capital will be available for an increasing number of projects, and opportunities for chemical engineers to undertake the simplifying, streamlining and cost-cutting developments will be greatly increased. Within a relatively few years, the nuclear field should provide an area of high employment and investment for the profession.

Illustration on first page of article represents an idealized conception of a nuclear power plant, minus the necessary auxiliary chemical processing plant. Reactor contains sodium as coolant. (Courtesy North American Aviation, Inc.)

Heavy Water

A Review of Processes and Plants for Large-Scale Production

Patrick J. Selak and Joseph Finke U. S. Atomic Energy Commission, Savannah River Operations

Heavy water, or deuturium oxide, is an important material of construction for nuclear reactors. It is an excellent moderator for the slowing of fast neutrons—about four times as efficient as graphite. In presenting this paper, we believe it to be of general interest not only because of the separation difficulties that had to be overcome, but also because of the probable application of the experiences gained to other large-scale separations of materials not necessarily related to nuclear engineering.

Methods used for the large-scale production of heavy water have been recently declassified. These include distillation and electrolysis of water, hydrogen-water exchange, and distillation of liquid hydrogen. These processes, the first three of which were used by the Manhattan Project (and to some extent are still being used) for the production of tonnage quantities of heavy water, are reviewed here from the standpoint of flow sheet, process engineering, description of those plants which have been built, and plant performance. This is a report on six plants built and operated for the government and one designed but not built.

Included are not only large-scale process design and plant operating-experience data of general value, but also information of direct benefit to private firms interested in heavy-water manufacture. As the authors point out, much cost-cutting is to be expected through the ingenuity of private enterprise.

As to market prospects, reduction of product selling price to below $40 a pound may attract interested customers in the field of nuclear power generation.—Editors.

The significance of heavy water both in the current program of the Atomic Energy Commission and potentially in the generation of electrical energy from nuclear fuels needs no emphasis. Low-cost, large-scale production of heavy water would influence nuclear power projects throughout the world (*1*).

Correlating the nuclear properties of heavy water with those of other neutron moderators (see Table 1) reveals that heavy water achieves neutron moderation better than any other known usable material. Within certain engineering limitations, heavy water can be used as a combined moderator coolant with natural uranium fuel in either the heterogenous (solid) or homogenous (dissolved and continuously recirculated) power reactor concept.

The principal deterrents to including heavy water in present-day nuclear-power production planning are limited availability and high cost. Since the only economics involved in heavy-water production in America have been predicated on government experience, it should be pointed out that these plants have not been constructed with economy as the primary factor of consideration; rather, they were intended to fulfill an urgent need.

A purpose of this paper is to stimulate interest in this material as a principal component in reactor design. Although the comprehensiveness of this paper is limited to some extent by remaining security requirements, it seems worth while to present the information available at this time.

The Problem

Heavy-water production requires separation of the naturally occurring deuterium isotope from a suitable hydrogenous raw material. In general, isotopic separations are effected by differences in the average behavior of the molecules and ions of different isotopes. The isolation of the deuterium isotope is suggested by certain of its chemical and physical properties relative to light hydrogen (Tables *2* and 6). For example, the relative boiling points of D_2O and D_2 to H_2O and H_2 indicate that these isotopes can be separated by distillation. The equilibrium data relating hydrogen gas and water suggest the enrichment of deuterium in the water in chemical exchange with hydrogen by a factor of 3 to 4 at equilibrium.

The mass ratio of D/H is 2, and statistically the separation of these isotopes might appear relatively simple. However, deuterium is contained in natural hydrogen to the extent of only about 150 p.p.m., and since the size of the equipment required to concentrate a given amount of isotope in a cascade system is about inversely proportional to the concentration of the isotope, it becomes apparent that the separation of deuterium from hydrogen or deuterium oxide from water in large quantities will require extensive facilities.

History

With U. S. nuclear-weapons development precipitated by World War II and the knowledge that Germany was working on a similar project, the Office of Scientific Research and Development contracted Harold C. Urey and his group at Columbia University in early 1941 to determine methods for the large-scale production of heavy water (*10*) to be used as an alternative moderator in the nuclear production of Pu in the

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Table 1.—Nuclear Properties of D_2O (2 and 3)

Scattering cross section (σ_s)	= 15.3 barns
Capture cross section (σ_c)	= 0.00092 barn
Slowing-down power ($N\sigma_s\xi$)	= 0.370 cm.$^{-1}$ *
Moderating ratio, $\sigma_s\xi/\sigma_c$	= 12,000 (graphite = 170, Be = 159, water = 72)
Diffusion length	= 100 cm.

* N = molecules/cc.
ξ = logarithmic mean energy loss per collision.

Table 2.—Physical and Chemical Properties of D_2O (4 and 5)

Maximum density	1.106 at 11.2° C. (H_2O = 1.000 at 4° C.)
Melting point	3.81° C. (H_2O = 0° C.)
Boiling point	101.43° C. (H_2O = 100° C.)
Critical temperature	371.5° C. (H_2O = 374.1° C.)
Relative viscosity (compared with water) at 20° C.)	1.25
Natural abundance (average)	0.0146% in normal water
Ionization constant (25° C.)	1.95×10^{-15} ($H_2O = 1.0 \times 10^{-14}$)
K_{11a}. $(HDO)^2/(H_2O)(D_2O)$ = 3.80 (25° C.)	
$K_{exp.}$ $(H_2)(HDO)/(HD)(H_2O)$ = 3.88 (25° C.)	

event of failure of graphite-moderated reactors.

It was decided that distillation, chemical exchange, and electrolysis were the only techniques readily applicable to hydrogen isotope separation. Further investigations led to the selection of the water-distillation and hydrogen-water exchange processes for immediate construction. The former uses well-established fractional-distillation methods and was selected because it required almost no development and plants could be constructed and started in minimum time. Special consideration was given to the catalytic exchange of deuterium between hydrogen gas and water vapor because of the advanced state of its development and the availability of a large source of electrolytic hydrogen at the Consolidated Mining and Smelting Company plant at Trail, B. C. This process, being dependent on electrolytic hydrogen, was recognized as limited in production capacity by the availability of this hydrogen. Electrolysis was employed as a finishing process in conjunction with both the preceding methods. The electrolytic process had been employed commercially by the Stuart Oxygen Company of San Francisco, California.

Specifications

Final deuterium oxide product specifications were established as follows: 99.7 wt. % deuterium oxide minimum concentration after O^{18} correction on any one shipment and 99.75 wt. % minimum average on all shipments; 6.0 to 6.6 pH; no removal of O^{18} necessary unless it exceeded normal concentration tenfold (which it never did); no specific limitation on impurities (however, chemical purity was controlled by a conductivity measurement on the final product distillate, and 15 micromhos/cm. was considered maximum permissible); a maximum permaganate demand was established at 1×10^{-5} g./ml. D_2O.

Water-Distillation Plants with Electrolytic Final Concentration

PRINCIPLES

The water distillation process is based on the difference in boiling points between water and deuterium oxide. Although this difference is small and it was recognized that the required energy consumption for fractional-distillation plants would not compare favorably with other methods, nevertheless the distillation process would enable considerable production of heavy water with a minimum of development effort. In the design of the distillation units it was necessary to assume that the vapor pressure of HDO is the geometric mean of the vapor pressures of H_2O and D_2O, that HDO follows Raoult's law in water, and that the plate efficiency would be 80%. Since the relative volatilities of D_2O, HDO, and H_2O are an inverse function of temperature and pressure, the distillation towers were designed to operate under vacuum.

In view of uncertainties in the design of the distillation process, an electrolytic plant for *final* product concentration was provided. The concentration of deuterium in the electrolyte during the electrolysis of a mixture of H_2O, HDO, and D_2O is probably based on a difference in discharge potentials at the electrodes. In the design of the electrolytic plant, it was assumed that the separation of deuterium and hydrogen was analogous to a simple batch distillation and could be expressed in terms of the Rayleigh equation. The over-all separation factor with carbon-steel cathodes and nickel-plated anodes was assumed to be about 7.

PLANTS

Plants for the separation of heavy water by distillation were designed, constructed, and operated by E. I. du Pont de Nemours at the Morgantown Ordnance Works, W. Va., (M.O.W.); Alabama Ordnance Works, (A.O.W.); and Wabash River Ordnance Works, Ind. (W.R.O.W.). These plants differed only in size, each consisting essentially of an eight-stage continuous vacuum-distillation train in which H_2O is stripped from the slightly less volatile heavy water (HDO and D_2O). The distillation plants concentrated the water to about 90% D_2O, the remaining separation of the semifinished product from all three plants being undertaken in the electrolytic finishing plant designed and constructed by Du Pont at Morgantown.

WATER-DISTILLATION PROCESS

Figure 1 illustrates the process flow through the eight stages.

The first stage of the distillation train consisted of a number of parallel units in groups of five; one group at M.O.W., two groups at A.O.W., and three at W.R.O.W. Each first-stage unit consisted of two towers in series, A,A′, functioning as a single fractionating column. The top or feed section, A, 15 ft. diam. × 100 ft. high, contained 80 tunnel-cap plates. The bottom section, A′, 12 ft. diam. × 106 ft. high, contained 90 bubble-cap plates. The feed to the first-stage distillation towers, steam condensate from the first-stage reboilers, entered the system at the top of the 15-ft.-diam. column, passed down the tower, and underwent a vacuum distillation wherein the less volatile heavy water became increasingly concentrated in the liquid phase. The vapor depleted in heavy water was drawn off from the tops of the first-stage units, condensed in barometric condensers, and discarded (except at M.O.W., where it was used as make-up for the cooling water to the condensers).

The concentrated material from the bottoms of the first-stage units was fed to the top of the second-stage units, B, B′, at a rate approximately equal to that of the boil-up of the latter. A second-stage unit, consisting of two towers functioning as a single column, was provided for each group of five first-stage units. The top section, B, of a second-stage pair, 10.5 ft. diam. × 83.5 ft. high, contained 72 bubble-cap plates; the bottom section, B′, 8 ft. diam. × 93 ft. high, contained 83 bubble-cap plates. The distillate from the second-stage units was returned near the bottom of the first-stage units at a point in the column having the same concentration. The liquid leaving the bottom of the second stage was so concentrated that the dissolved solids had to be removed by evaporation. Condensate from the evaporator was fed to the top of the third-stage column, C.

In each succeeding stage the flow was essentially the same: the feed to the stage was

Table 3.—Design and Operation of Manhattan Project Water Distillation Plants

	M.O.W.	A.O.W.	W.R.O.W.
Diameter and height of first-stage towers	15 × 100 ft. and 12 × 107 ft.	15 × 100 ft. and 12 × 107 ft.	15 × 100 ft. and 12 × 107 ft.
Number of first stages in parallel	5	10	15
Number of stages	8	8	8
Design % extractive	3.7%	3.4%	3.7%
Design draw-off concentraion	99.94%	99.94%	99.94%
Actual draw-off concentration	90%	90%	88%
Hold up at 90% draw off (lb. of 100% material above 0.02%)	975 lb.	1,185 lb.	2,424 lb.
Design production rate	800 lb./month	1,600 lb./month	2,400 lb./month
Maximum production rate achieved, lb./month	576 (72%)	640 (40%)	1,320 (55%)
Average production rate, lb./month	521 (65%)	598 (37%)	1,266 (53%)
Total production (12/43-9/45), lb.	12,000	11,000	27,000
Average actual operating cost/lb.	$140	$250	$155
Actual construction cost	$3,490,000 *	$3,466,171	$7,493,000
me between startup and initial draw-off	4½ months	5½ months	4 months

* Includes electrolytic finishing-plant processing output of all three primary plants.

liquid from the base of the preceding stage, and the vapor from the top of the stage was condensed and returned to near the bottom of the preceding stage. The third stage, *C*, was a single conventional bubble-cap tower containing 71 plates and a deentrainment plate with diameters of 66 in. at W.R.O.W., 54 in. at A.O.W., and 40 in. at M.O.W. The fourth-stage tower, *D*, was 30 in. in diam. and contained 72 bubble-cap plates at W.R.O.W., 2 ft. in diam. with 72 plates at A.O.W., and 18 in. in diam. packed with ⅝-in. ceramic rings at M.O.W. The fifth, sixth, seventh, and eighth stages, *E*, were packed towers: 18 in. in diam. × 72 ft. high at W.R.O.W., 16 in. in diam. × 72 ft. high at A.O.W., 10 in. in diam. × 72 ft. high at M.O.W. The product from the eighth stage was given a final evaporation preparatory to its shipment to the finishing plant.

CONSTRUCTION SCHEDULE AND INVESTMENT

Construction of these plants was initiated in January and February of 1943, portions were in operation by June, 1943, all construction was completed by November, 1943, first product shipment was made in January, 1944, and equilibrium concentrations were established by May, 1944. The combined construction cost about $14,500,000 and required 13,750 man months. The plants were designed to produce 2,400, 1,600, and 800 lb. D_2O/month at W.R.O.W., A.O.W., and M.O.W. respectively.

EFFICIENCIES ATTAINED

In actual operation the distillation plants attained about a 50% average efficiency. The maximum capacity realized at the three plants was 1,320 lb. deuterium oxide as 90% product per month at W.R.O.W., 640 lb./month at A.O.W., and 576 lb./month at M.O.W. These low yields were attributed pri-

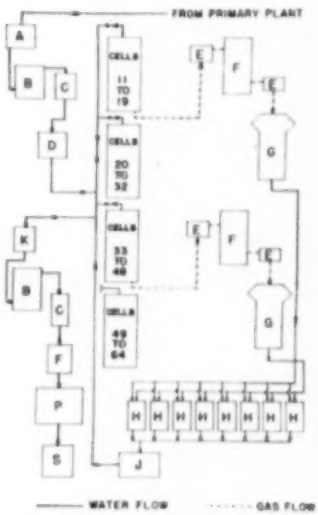

Fig. 3. Process flow for electrolytic finishing plant at Morgantown Ordnance Works.

Legend: A—incoming product tank; B—evaporator; C—condenser; D—electrolyte mixing tank; E—separator; F—cooler; G—burner-condenser; H—selection (cut) tanks; J—electrolyte mixing tank; K—carbonate mixing tank; P—final product tank; S—shipping drum.

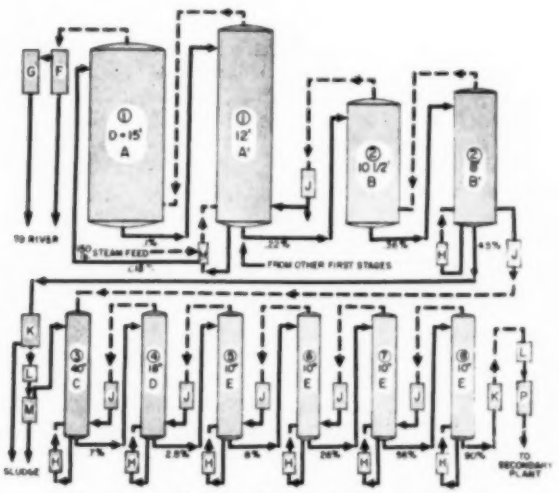

Fig. 1. Simplified flow diagram for the concentration of D_2O by distillation.

Legend: A, A'—first-stage towers; B, B'—second-stage towers; C—third stage towers; D—fourth-stage towers; E—towers, stages 5 to 8; F—barometric condenser; G—steam ejector; H—reboiler; J—falling film condenser; K—evaporator; L—condenser; M—settling tank; P—product draw-off tank.

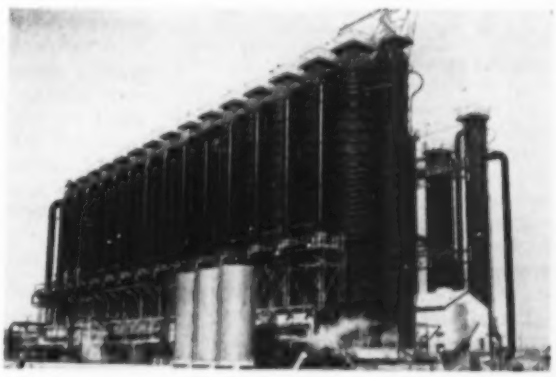

Fig. 2. Photograph of water distillation plant at Wabash River Ordnance Works. In the foreground are the fifteen first-stage towers. In the background can be seen the operating building and the second-stage towers.

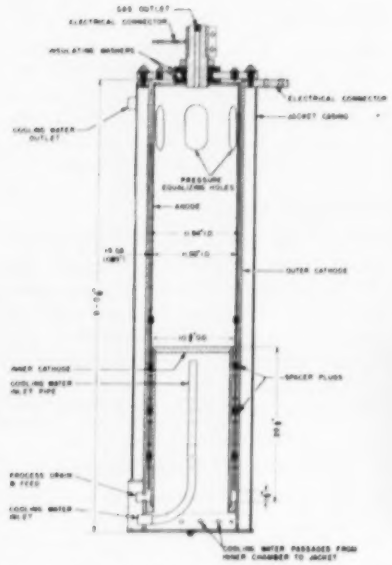

Fig. 4. The cathodes and cell structure are made of mild steel; the anodes are usually nickel or nickel plated.

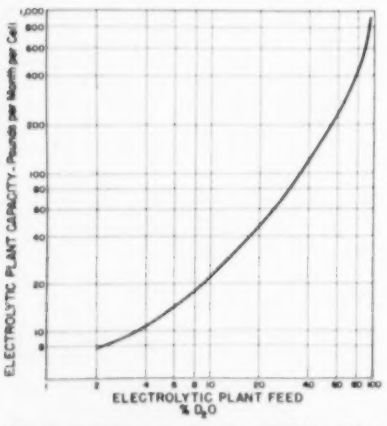

Fig. 5. Variation of electrolytic finishing plant capacity with feed composition. This curve predicts the number of pounds of 99.75% D_2O/month obtainable per electrolytic cell as a function of input concentration. This curve is based on separation factors and innages achieved in operating plants. The shape of the curve is based on theoretical considerations since the only plant values available are at feed concentrations of 85-90% and at 2.37%.

marily to low plate efficiencies in the initial stages of the distillation train. For example, plate efficiencies at A.O.W. were 35 to 40% in the first-stage columns compared to the 80% design estimate. First-stage plate efficiencies at W.R.O.W. were 45% and at M.O.W. 50%, primarily, it was believed, because of faulty plate construction resulting in excessive plate leakage and irregularities in the flow of vapor and liquid over the plates. Plate designs and fabrication techniques were based on completing construction fast because of urgent need for the product.

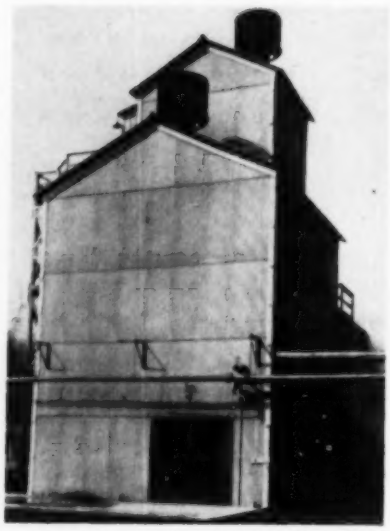

Fig. 6. Photograph of electrolytic finishing plant at Morgantown Ordnance Works. The high bay contains the burners. The condensate flows by gravity to the selection (cut) tanks and then back to the cells.

Despite operating setbacks resulting from hurried construction, the distillation plants produced the major portion of the initial project requirements for heavy water.

CORRECTION MEASURES

A first-stage tower pair at M.O.W. was completely dismantled, one third of the bubble caps on all plates of the 12-ft. tower were removed to reduce the hydraulic gradient causing flow irregularities, and all seams and joints at all plates of both towers were gasketed or welded to reduce the by-pass leakage. The cost of this alteration was about $72,000 and 24 days downtime. Operation of the plant at Morgantown after completion of this work indicated that the altered first-stage towers were operating at very close to design efficiency. It was estimated that similar reconstruction of all the remaining first-stage towers at the three plants would cost about $2,200,000, and require six months to complete. Since an approximate balance between supply and demand for the product would have been reached by the time this work could have been completed and the increased output made available, it was decided not to undertake the alterations.

OPERATING EXPENSE

Monthly operating costs for the three distillation plants were about $200,000, $150,000, and $73,000 respectively at W.R.O.W., A.O.W., and M.O.W. Of the combined operating costs for the three plants approximately 70% was chargeable to steam, 7% to labor, 10% to water, 3% to maintenance, 1% to electrical power, and 9% to overhead. These components varied somewhat at the different sites. For example, coal charges were substantially lower at M.O.W.

Table 3 summarizes the principal design and operating features of the distillation plants.

ELECTROLYTIC FINISHING PROCESS

The electrolytic plant located at M.O.W. was designed to process 9,600 lb./month of 50% deuterium oxide product from the three distillation plants; it actually received and handled about 2,400 lb./month of 90% deuterium oxide.

The semifinished product from the eighth stage of the distillation plants was evaporated in a Dopp kettle with $KMnO_4$ to oxidize organic contaminants, and the condensate was mixed with electrolyte to form a 7.5% K_2CO_3 solution and fed to cells 33 to 48 (Figure 3). The mixture of oxygen and hydrogen evolved in the electrolysis was collected in a common header, which was heated to prevent condensation of vapor; the mixture was then passed through a liquid-gas separator, an NH_3 cooler to condense vapor, another separator, and then to a burner condenser, where the oxygen and hydrogen were recombined by combustion and condensed. The condensate from the burned gases was transferred to cut tanks, where it was held according to concentration. After the concentration reached 99.4% heavy water (at which time the cell electrolyte was at least 99.8% heavy water), the electrolyte residue from cells 33 to 48 was drawn off and again evaporated. The condensate from this evaporation was measured for conductivity and pH before it was transferred to the product vessels.

Cells 11 to 32 were used for processing concentrations with less than 80% D_2O, and cells 33 to 48, for concentrations greater than 80% as well as for the feed from the distillation plants. Cells 49 to 64, which represented excess capacity, were fed with normal water to serve as a ballast to maintain the minimum load requirements on the rectifier. Cells 1 to 11, diaphragm-type cells installed to remove excess O^{18} from the D_2O product, were never used.

The electrolytic cells (Figure 4) employed in this operation are so-called *concentration* cells, in which the gaseous products of electrolysis are combined, as contrasted with cells of the *diaphragm type*, in which H_2 and O_2 are evolved separately. Each cell, about 5 ft. high and 16 in. in diam., had a charge capacity of about 100 lb. of solution and was equipped with water-cooled inner and outer carbon-steel cathodes and concentric nickel anodes. A current of 1,000 amp. passed through the cells, which were connected in series. This current electrolyzed about 0.74 lb. of water/hr./cell, and the voltage ranged from 2.6 to 3.4 v. (at greater than 3.5 v. the electrodes tend to decompose). Cell-cooling water at 25° C. maintained cell temperature at 40° C. The conditions which affected adversely the separation factor in this electrolysis

Fig. 8. View of the secondary plant cell room at Trail, B. C.

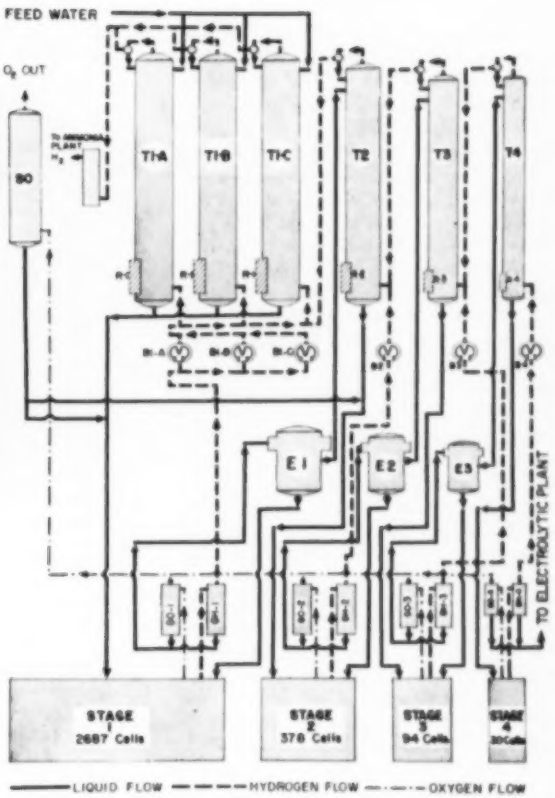

Fig. 7. Simplified flow diagram for hydrogen-water exchange plant (employed at Trail, B. C., plant of Consolidated Mining & Smelting Co., Ltd.).

Legend: T1-A, B, C—first-stage exchange towers; T2, T3, T4—second-, third-, and fourth-stage exchanger towers; R-1, 2, 3, 4—re-boilers; SO—oxygen scrubber; B1-A, B, C—first-stage blowers; B2, B3, B4—second-, third-, and fourth-stage blowers; E1, E2, E3—first-, second-, and third-stage evaporators; GH-1, 2, 3, 4—hydrogen evaporators; GH-1, 2, 3, 4—hydrogen coolers GO-1, 2, 3, 4—oxygen coolers.

were contaminated feed, poor electrode surfaces, vaporization of liquid, entrainment and foaming of liquid, high cell-liquor temperatures, and electrode polarization.

The burner-condenser was a vertical, water-jacketed, cylindrical chamber in the top of which the gases were recombined by burning in an excess of oxygen. The water vapor formed was condensed on the jacket walls. The gases were ignited in the burner by one or two hot-wire-type electrical-resistance ignitors located adjacent to the orifice through which the gases were burned. Fluctuations in the velocity of the gas through the orifices can cause the flame to strike back to the slower moving gases in the process gas lines, causing an explosion. This phenomenon, called a *flashback*, represented one of the operating hardships in the electrolytic process. To help prevent flashbacks through the gas lines the gas velocity to the burner nozzles must be in excess of the propagation rate of a hydrogen-oxygen flame (21.7 ft./sec.). In actual operation flashbacks occurred several times a month from electrical shorts in the cell, pulsations of current, impurities in the gas stream, or pressure fluctuations.

COSTS

Estimated production of pounds per month per cell of an electrolytic finishing plant as a function of feed concentration is plotted in Figure 5. The finishing-plant building at M.O.W. (see Figure 6) cost in the neighborhood of $50,000 and the equipment, consisting of the electrolyte cells, tanks, pumps, burners, condensers, rectifier and associated switch gear, etc., cost about $208,000. Operating costs for this facility were incorporated in the over-all operating costs of the distillation plants. (For an estimted unit cost, see Table 5 and Figure 5.)

Hydrogen-Water Exchange with Electrolytic Finishing Plant

PRINCIPLE

The hydrogen-water-exchange process is based on the tendency of deuterium to transfer to (and thus concentrate in) water more rapidly than in hydrogen in the chemical exchange reactions:

$$H_2O + HD \rightleftarrows HDO + H_2$$

$$HDO + D_2 \rightleftarrows D_2O + HD$$

A catalyst being required for practicable equilibrium conditions, it was determined that platinum (on a charcoal base) and nickel-chromia catalysts were effective in establishing this equilibrium rapidly in the vapor phase. In the first reaction above, which is applicable to the process conditions employed, the vapor-phase equilibrium constant, $(HDO)(H_2)/(H_2O)(HD)$, varies from 3 at 20° C. to 2 at 100° C. Thus if a H_2 and HD gas mixture is contacted with H_2O vapor over a catalyst, HDO is formed. The HDO may then be scrubbed out of the vapor phase with water, the vapor mixture again passed over the catalyst, equilibrium reestablished, and more HDO removed by scrubbing. If this catalytic exchange reaction and equilibration of the water vapor with the scrubbing water is repeated a number of times in a counterflow cascade system, appreciable enrichment of deuterium in water can be achieved.

PROCESS—PRIMARY PLANT

The hydrogen-water exchange process is incorporated into the Consolidated Mining and Smelting Company's (C.M. & S.) electrolytic hydrogen-production plant at Trail, B. C., and called the primary plant. Feed to the primary plant is ordinary steam condensate containing 0.014% D_2O, which as vapor in exchange with the hydrogen gas generated in the C.M. & S. electrolytic hydrogen plant is concentrated in a series of four stages to about 2.3% D_2O. In essence, the hydrogen produced by C.M. & S. is borrowed for the purpose of extracting its deuterium content and then returned to C.M. & S. for the synthesis of NH_3. Final concentration takes place in a three-stage electrolytic process, called the secondary plant.

The primary plant processing scheme at equilibrium conditions (see Figure 7) is as follows. The steam condensate fed to the top of the first-stage towers (two operating in parallel, one

maintained as spare) becomes enriched in deuterium at the expense of upflowing hydrogen gas from the first-stage cells and the second-stage towers through the series of alternate catalytic exchange reactions and scrubbing steps (as described above). On leaving the towers the enriched water is fed to the first-stage cells and electrolyzed to generate hydrogen while further increasing the concentration of D_2O in the electrolyte. The hydrogen is fed back to the base of the first-stage towers via a deentrainment condenser. At the base of each tower a reboiler is provided so that part of the water in the tower may be converted into vapor which is added to the hydrogen rising through the tower. At the top of the towers condensers are provided to reflux water entrained in the outflowing hydrogen. Depleted hydrogen from the top of the first-stage towers is utilized in the C.M. & S. ammonia-synthesis plant. Entrained first-stage cell liquor, condensed out of the generated hydrogen and oxygen, is purified by evaporation, fed to the top of the second-stage towers, and contacted with hydrogen generated in the stage-two cells (and also from the third-stage towers). Hydrogen leaving the top of the second-stage tower is sent to the base of the first-stage towers. The cell liquor entrained in the generated second-stage cell gases is separated in condensers, evaporated, and fed to the top of the third-stage towers.

Essentially this same operation is carried out in each remaining stage of the cascade. Feed water for the exchange tower is purified cell liquor separated from the hydrogen and oxygen generated in the preceding stage. The hydrogen gas leaving the top of the tower is fed to the base of the preceding-stage tower; each tower is also fed with hydrogen generated from its own bottom liquid. Although the equipment remains essentially the same, it becomes progressively smaller in each succeeding stage as the concentration of D_2O in the electrolyte becomes higher.

The three first-stage towers in the primary plant are 8.5 ft. I.D. by 112 ft. high, the second-stage tower is 5 ft. I.D. by 108 ft. high, the third-stage tower is 2.5 ft. I.D. by 97 ft. high, and the fourth-stage tower 1.5 ft. I.D. by 96.5 ft. high (see Figure 9). Each tower contains thirteen alternate sections of catalyst trays and bubble-cap plates. Since the catalyst does not operate satisfactorily if wet, the scrubbing water must be by-passed around each catalyst section, and heaters provided to dry the gas stream before it enters the catalyst bed (see Figure 10). In conjunction with the first-stage exchange towers 2,687 diaphragm cells were used; with the second stage, 378 cells; third stage, 94 cells; and fourth stage, 30 cells.

PROCESS—SECONDARY PLANT

Approximately 2,200 lb./day of water containing 2.3% D_2O is fed to the secondary plant (Figure 8), where it is concentrated to product specifications by electrolysis. Except that concentration is carried out in three stages, the design and techniques are similar to those described for the finishing plant at Morgantown.

Table 4.—Construction and Operation of Hydrogen-Water Exchange Plant (Located at Consolidated Mining and Smelting Company, Ltd., at Trail, B. C.)

	Stage 1	Stage 2	Stage 3	Stage 4
Number and diameter of towers	3 × 8.5 ft.	1 × 5 ft.	1 × 30 in.	1 × 18 in.
Catalyst composition	Platinum	Platinum	Platinum	Ni-Cr_2O_3
Quantity of catalyst, lb./tower	7,440	3,441	737	486

Material of construction: copper
Draw-off concentration: design = 2.5-3.0%, actual = 2.37% D_2O
Extraction of D_2O from feed: theoretical = 50%, actual = 43%
Production, lb./month: design = 1,200, actual = 1,100
Time to reach equilibrium: 15-18 months
Operating cost/lb. (1953): $60 (excluding secondary plant, but including overhead and profit to C.M.&S.)
Actual construction cost: $2,400,000 (excluding secondary plant)

Table 5.—Design Features of a Typical Electrolytic Concentrating Plant (Based largely on Secondary Plant at Trail, B. C.—1,100 to 1,200 lb. D_2O/month from 2.3% feed)

Number of cells	150
Dimensions	16-in. diam. × 5 ft. high
Materials: cathode (shell)—steel; anode—nickel or nickel plate	
Voltage drop per cell	2.5-3.0 volts
Power required per cell	2.5-3.0 kw.
Separation factor (alpha)	7.0-9.0
Electrolytic composition	K_2CO_3
Burners required	4 to 6
Estimated present construction cost	$500,000 to $1,000,000
Operators required	4 per shift—operating 2 to 4 per shift—laboratory 2 to 3 per shift—maintenance ½ per shift—instruments

Table 6.—Comparison of Volatility of Hydrogen and Deuterium

	H_2	HD	D_2
Normal boiling point, ° R.	36.68°	39.83°	42.37°
Boiling point at 30 lb./sq.in.abs., °R.	41.7	44.7	47.5
Vapor pressure at 40.5° R.	26.12 lb./sq.in.abs.	16.34 lb./sq.in.abs.	10.58 lb./sq.in.abs.

Ratio of vapor pressures at 40.5° R. (H_2/HD) = 1.598
Relative volatility (allowing for deviations from ideal solution laws) = 1.392

Table 7.—Design Features of a Hydrogen Distillation Plant (Based on H.R.I. design)

Proposed location: Phillips Chemical Co., Etter, Texas (ammonia plant)

Production achievable at that site	34 tons/year
Design % extraction	95
Operating pressure: stills = 25 to 30 lb./sq.in.abs., compressor discharge = 425 lb./sq.in.abs.	
Operating temperature	—419° F. (41° R.)
First-stage tower	141 ft. high × 13 ft. diam.
Estimated construction cost	$9,300,000 ($135/lb./year)
Estimated operating cost	$1,000,000/yr. ($15/lb.)

CONSTRUCTION AND INVESTMENT

Construction of the Trail heavy-water facilities started in September, 1942; the secondary plant was transferred to operations in May, 1943, and the primary plant in June, 1943. The cost of construction was approximately $2,600,000, which included about $200,000 for development, $1,700,000 for new buildings and equipment, $213,000 for alterations and rearrangement of the existing C.M.&S. plant, and $466,000 for catalysts.

COLLABORATORS

In addition to Dr. Urey and his coworkers at Columbia University, who developed the process fundamentals, other contributors included H. S. Taylor at Princeton, who developed the platinum catalyst employed in the process; F. T. Barr of Standard Oil Development, exchange tower concept; and M. Dole and A. O. C. Nier, analytical techniques. The engineering, design, procurement, and construction of this plant involved Consolidated Mining and Smelting Company—erection of ex-

Fig. 9. View of primary plant at Trail, B. C., showing exchange towers; this photograph was taken before walls of building were installed.

change towers, adaptation of their hydrogen plant, and construction of the secondary plant (with assistance from Stuart Oxygen Company); Stone and Webster Corporation—procurement and management; Standard Oil Development Corporation—detailed design of the tower system; and E. B. Badger and Sons—mechanical design.

OPERATING EXPERIENCE AND EXPENSE

In general the plant was free from major operating problems and performed close to design efficiency: approximately 1,100 lb. D_2O produced/month compared to 1,200 lb./month design capacity. Some losses from the primary-plant cells were experienced, and flashbacks similar to those described at the Morgantown plant were a continuous problem in the secondary plant. During the Manhattan Project, the incremental cost to C.M. & S. for operating this plant averaged less than $30,000/month (approximately 20% of this was chargeable to the operation of the secondary plant). To this cost was later added a charge of 30% to cover a prorated share of the cost for electrical power and production labor required to operate the C.M.&S. hydrogen plant. Indirect and overhead expenses bring the unit cost for heavy water produced at Trail to more than $60/lb. at the present time.

Liquid-Hydrogen Distillation Plant

PRINCIPLE

As indicated in Table 6, there is a significant difference in boiling points between H_2, HD, and D_2, with a high relative volatility obtainable at the pressures which are useful for this process. This high relative volatility not only decreases the total number of theoretical plates required to obtain a given concentration of deuterium, but makes it feasible to "strip" the depleted hydrogen to a very low HD content, and thus obtain high recoveries.

The major problems associated with this process include the operation of plant-size mechanical equipment at the extremely low temperatures (−419° F.) required in the hydrogen liquefaction and rectification steps, the formation of solid deposits at these low temperatures from impurities in the feed (N_2, O_2, etc.), and the safety problems concomitant with the use of large quantities of liquid hydrogen. Because of these problems and other engineering uncertainties, this process was not selected for construction by the Manhattan Project; it was felt that other processes required less development and had a greater probability of success. However, it has been predicted (*6*) that low-temperature hydrogen distillation will produce heavy water at a lower cost than any of the processes previously considered.

FEASIBILITY

Post-war developments in low-temperature technology (oxygen-nitrogen distillation plants, etc.) made this process appear more practicable. During 1949 and 1950 a study was made by Hydrocarbon Research, Inc., under U.S.A.E.C. contract for the design of a plant to produce 30 to 40 tons of D_2O/year by distillation of liquefied hydrogen obtained from gas (N_2-H_2 mixture) used in ammonia synthesis. Since this process uses as its feed large quantities of hydrogen gas, heavy-water plants using low-temperature distillation are inevitably "parasitic" in nature; that is, they "borrow" their feed from an existing chemical plant using hydrogen, remove the deuterium, and return the stripped hydrogen. It was found that heavy-water facilities with a capacity greater than 20 tons/year could be installed in at least nine plants in the United States. Of these the preferred locations were at three large ammonia-synthesis plants using natural gas as a raw material for the production of hydrogen.

A detailed design was prepared based on the location of this facility at the Etter, Texas, plant operated by the Phillips Chemical Company. Some of the principal features of this plant are summarized in Table 7. The hydrogen available at this site is slightly depleted in deuterium compared with its normal abundance because of the process used to produce the hydrogen. This deficiency can be rectified by changes in the hydrogen-producing plant estimated to cost about $750,000, which is not included in the cost given in Table 7. Although this particular plant was never built, it represents a good example of low-temperature plant design.

PROCESS

As shown in the flow diagram, Figure 11, synthesis gas (70% N_2, 24% H_2, 6% CH_4, CO, CO_2, O_2, A, etc.) is received from the ammonia plant at 245 lb./sq.in.abs. The mixture is compressed to 425 lb./sq.in.abs. and cooled to 116° R. (−344° F.) in exchangers FX-1 and FX-2 at a point where most of the nitrogen liquefies and is separated in the liquid-nitrogen separator, NS. The hydrogen is expanded in an engine to 245 lb./sq.in.abs. and 60 to 62° R., the temperature at which it is fed to the primary HD tower, T-1. The bottoms from this tower contain 7% HD and are fed to the second-stage HD tower, T-2, where the hydrogen is concentrated to 94% HD. In order to concentrate the product further, the bottoms of tower T-2 are warmed up to 560° R. (100° F.) and the reaction $2HD \rightleftarrows H_2 + D_2$ is catalyzed (with a nickel-chromia catalyst) in the reactor, R. This stream is recooled to 45° R. and fractionated in the D_2 tower, T-3, to 99.75% D_2; then it is burned with oxygen in the burner, B, to give specification-level D_2O.

The overheads from the D_2 tower and the second-stage HD tower are returned to the second stage and primary HD towers respectively. The stripped overhead from the primary HD tower is split; part of the stream is returned to the feed heat-exchanger system, where after cooling the feed stream it is recombined with the nitrogen, which had been condensed out of the feed, warmed up to normal temperatures, and returned to the ammonia plant. About 65% of the stripped hydrogen from the top of T-1 is sent to the auxiliary heat-pump system, AX, C-4, and AC. It acts first as a heat source for the reboiler, where it is condensed, and then as liquid-hydrogen reflux to the top of the primary HD tower.

DESIGN FEATURES

Figure 12 is a photograph of a model of the plant designed by Hydrocarbon Research, Inc. The large Hortonsphere acts as a surge tank for the stripped hydrogen leaving the heavy-water plant. The structure on the left is a cooling tower; in the center is the compressor house; and on the right is the cold box, which contains all the vessels, piping, towers, exchangers, etc., which operate at subzero temperatures.

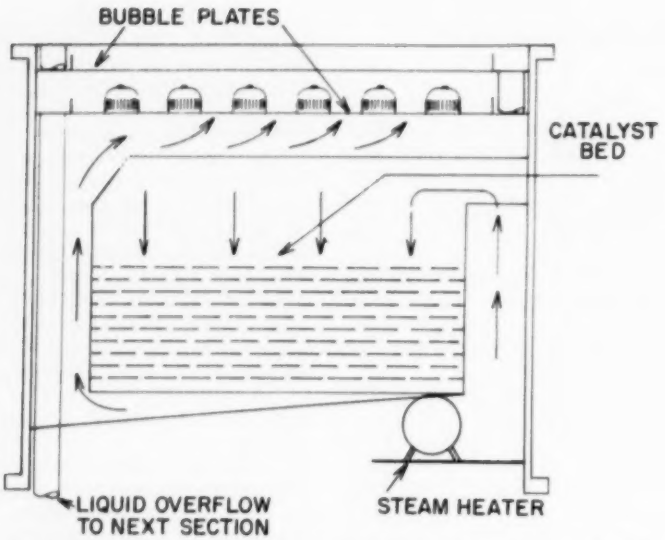

Fig. 10. Schematic cross section of hydrogen water exchange tower. There are 13 of these sections, consisting of a catalyst bed and two bubble-cap trays in each exchange tower.

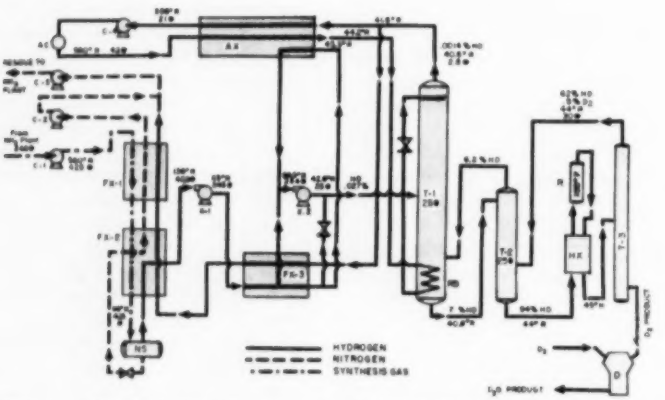

Fig. 11. Simplified flow diagram of a typical hydrogen distillation heavy water plant.

Legend: T-1—primary HD tower; RB—reboiler; T-2—second-stage HD tower; T-3—D_2-HD tower; R—HD shift reactor; HX—HD shift echanger; FX-1, 2, 3—feed heat exchangers; AX—auxiliary heat pump exchanger; AC—after-cooler; C-4—heat pump compressor; C-3—feed compressor; C-2—nitrogen compressor; C-1—residue gas compressor; N5—nitrogen separator; X-1, 2—expanders; B—burner.

The cold box is a gas-tight enclosure filled with hydrogen gas at a few inches of water gauge pressure and containing Santocel or Pearlite insulation at a minimum thickness of 5 ft.

The primary tower, insulated with an 18-in. annular vacuum jacket, is surrounded by sheet-metal walls and a roof to relieve it of wind loads. It is an 80-tray bubble-cap tower 13 ft. in diam. by 141 ft. high, containing a reboiler as an integral part. The other towers consist of several 6-in. I.D. tubes containing Stedman packing; the secondary HD tower has twenty-seven tubes with about 7 ft. of packing each; and the D_2 tower has three tubes with 22 ft. of packing each.

Two classes of equipment whose performance is critical for a plant of this type are the expanders and the heat exchangers.

The expanders consist of pedestal-type, three-stage radial-reaction turbines, the energy output of which is dissipated in low-efficiency gear pumps as heat. The expander proper is separated from the gear pump by a double labyrinth seal with a gaseous hydrogen feed between the two seals.

Three types of heat exchangers are used in the plant: shell-and-tube, flat-plate, and harp. The shell-and-tube exchangers are fairly conventional, and the flat-plate exchanger is similar to exchangers manufactured by the Trane Company of La Crosse, Wisconsin. Flat-plate exchangers are the most compact type of extended-surface exchanger for low-temperature duty but they are limited to fairly low pressures. For the high pressures the harp-type exchangers were developed. These are finned, vertical concentric tubes connected in banks by horizontal headers. Exchangers in which solids are deposited (largely N_2) are the reversing type. In this latter design inlet gas containing appreciable condensables flows in one passage countercurrent to the effluent gas. After a significant quantity of solids has been deposited, the two streams are switched; the effluent gas flows in the passage which previously contained inlet gas, and the deposited solids are evaporated into this effluent stream. This type of operation is often used in oxygen plants, where a similar problem of solids deposition is encountered.

Conventional materials of construction are used in the portion of the plant operating at temperatures above 0° F., and either type-304 E.L.C. stainless steel or aluminum is used at subzero temperatures.

The only unproved features of the design prepared by Hydrocarbon Research, Inc., is the operation of the expanders and the reversing exchangers. Assuming that these two devices can be operated satisfactorily, this should be one of the more attractive processes for producing heavy water. As can be seen in Table 7, the estimated construction and operating costs are considerably lower than those of any of the wartime heavy-water plants.

Other Processes

A number of other processes for the separation of heavy water conceived during the initial development work at Columbia University included the use of separating agents in the extraction or distillation of heavy water from natural water and a number of dual-temperature exchange methods.

Extraction agents were investigated for a number of systems including liquid-liquid extraction, extractive distillation, and azeotropic distillation. For example, it was believed that triethylamine would preferentially strip heavy water from natural water, but Du Pont, contracted to investigate the possible use of this agent in conjunction with the water-distillation plants, showed that it was not feasible, and the research was abandoned.

The dual-temperature separation technique was originally suggested by A. Farkas in Germany and E. K. Rideal in England(*8*)and adopted by the group at Columbia University for development as a possible method of heavy-water production. The separation of isotopes by a dual-temperature exchange process is based on the variation of exchange equilibria with temperature, and the separation efficiency is a function of the temperature differential which can be maintained in the system. For example, if water and another hydrogen-containing fluid (H_2S, NH_3, R-SH, etc.) are equilibrated at two temperatures, a point of maximum deuterium concentration is established from which product can be drawn off.

Fig. 12. Model of hydrogen distillation heavy water plant. In the model the walls of the compressor house and the "cold box" are constructed of Plexiglass in order to reveal the internals.

Among the dual-temperature methods considered early in the Manhattan Project was a hydrogen sulfide–water exchange in which the deuterium isotope is concentrated in the feed water by exchange with enriched hydrogen sulfide in a cold tower, partially drawn off for succeeding stages in a cascade, and stripped from the water by equilibrium with hydrogen sulfide in a hot tower. Depleted water is discarded (or sent back to a preceding stage), and the hydrogen sulfide recycled to the cold tower. The process was based on the variation of equilibrium constants with temperature for exchange reactions:

$$HDS + H_2O \leftrightarrows HDO + H_2S$$
$$HDO + HDS \rightleftarrows D_2O + H_2S$$

This process was not used by the Manhattan Project because of many engineering uncertainties and the predicted corrosiveness of the system.

A dual-temperature mercaptan-water exchange similar in principle to the hydrogen sulfide–water exchange methods was also investigated at Columbia. It was believed that mercaptans would not be so corrosive as hydrogen sulfide. However, further investigations indicated that this method could not compete with other processes being considered at that time and work was abandoned.

Another dual-temperature process considered was a three-component system involving the reactions:

$$H_2O + NH_2D \rightleftarrows HDO + NH_3$$
$$HDO + H_2 \rightleftarrows H_2O + HD$$
$$HD + NH_3 \rightleftarrows NH_2D + H_2$$

Feed water is concentrated in deuterium through exchange with ammonia which has previously been enriched in a cold-tower exchange with hydrogen. The hydrogen recovers its deuterium by a hot-water catalytic exchange with the enriched water. Prior to this latter exchange a portion of the enriched water is drawn off for further enrichment in succeeding stages. Depleted water from the hydrogen-water exchange is discarded (or sent back to a preceding stage). The ammonia and hydrogen components are kept in continuous recycle.

Future Development

It is evident that there is no technological barrier to the tonnage-scale production of heavy water. Manhattan Project experiences were based on a need for large quantities of heavy water in a minimum of time and did not result necessarily in selection of the best process in regard to capital and operating costs and production potential; nevertheless, the water-distillation and hydrogen-water catalytic-exchange processes might be reappraised on the basis of new design possibilities by use of such criteria as

1. Location of heavy-water plants near cheap sources of energy (natural gas, geothermal steam, etc.).
2. Use of vapor recompression with the water-distillation process.
3. Development of new tower designs for the water-distillation process.
4. Revised cascade for the hydrogen-water exchange process. (There is probably twice as much catalyst in the Trail plant as is required).
5. Development of a liquid-phase catalyst for the H_2–H_2O exchange process.
6. Development of an exchange catalyst which could be used with hydrogen produced from water gas or other nonelectrolytic sources of hydrogen.

The liquid-hydrogen distillation process is considered less expensive to build and operate than are the processes employed by the Manhattan Project. Like the primary plant at Trail, however, this process is limited by the availability of large amounts of hydrogen gas.

Some of the other methods discussed, such as extractive distillation and dual-temperature exchange, might with further development prove to produce heavy water at lower cost than do the other processes considered. The marginal cost for heavy water for economical production of nuclear power is thought to be about \$40/lb. Unit costs currently reported for this material in this country and Europe have ranged from \$60 to \$100/lb. The production of heavy water at less than \$40/lb., including amortization, is in the opinion of the authors within the realm of possibility, not however without further development and plant design. It is hoped that as a result of the increasing interest of private industry in developing peacetime use of nuclear energy such a program will be forthcoming.

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Uranium and fabrication

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Basic to the generation of nuclear power is the preparation of pure uranium metal. There are many ways of accomplishing this. Details of current production methods of the United States have not been published, but from Belgium we present a paper on a method of preparation developed and used by the Belgium atomic energy project. Outlined are some of the problems met in producing this important metal—the only naturally occurring nuclear fuel.

Chemical and metallurgical researches and developments associated with uranium metal extraction and fabrication were started on behalf of the Institut Interuniversitaire des Sciences Nucléaires in late 1947 (*4*) at the Brussels University under the supervision of Professor C. Decroly, head of the electrochemistry and metallurgy departments. Subsequently the Centre d'Etudes pour les Applications de l'Energie Nucléaire took over the project, and now sponsors all the applied research work in the nuclear energy field.

Historical

Uranium metal powder was produced for the first time by Peligot (*17*) in 1841 by reduction of UCl_4 with potassium.

In the numerous researches on uranium metal preparation, an attempt was made to reduce the oxides with carbon, Norman (*15*), the alkali and alkali-earth metals, Marden (*13*), Jander (*8*), Botolfsen (*2*), and to reduce the halogens of uranium by the alkali and alkali-earth metals, Zimmerman (*19*), Moissan (*14*), Lely and Hamburger (*11*), Moore (*16*), Goggin (*6*), Marden (*12*) and W. Kroll (*10*). The electrolytic powder preparation from $UCl_4.2$ NaCl was studied by Moissan (*14*), that from KUF_5 by Driggs and Liliendhal (*5*). All the metal prepared by this method was highly contaminated with oxygen, and indications on the melting point were of the order of 1,600–1,800° C.; no process was developed on an industrial scale.

The first metal produced on an industrial scale was fabricated by the Westinghouse company, which had developed a method for producing an electrolytic powder from the complex salt KUF_5, later substituted by UF_4 (*3*). A new process was worked out in 1942 by F. H. Spedding at Iowa State College, Ames, based on the reduction of uranium fluoride by calcium. A production plant was set up under the supervision of W. H. Wilhelm.

In Germany, during the same period, Degussa produced a few tons of uranium by reduction of the oxide U_3O_8 with calcium (*18*).

In France research on uranium metal fabrication started in late 1948, when a process was developed on an industrial scale. The French process for uranium metal extraction is essentially based on the calcium reduction of uranium tetrafluoride prepared by the "humid way." This way consists in attacking UO_2 with a solution of hydrogen fluoride at 40%, followed by filtration and desiccation. The desiccation of the fluoride needs much care as humidity is responsible for the lowering of the yield and quality of the metal (*7*).

In Great Britain a small production plant was operating by 1947 (*9*) according to a process developed by the Imperial Chemical Industries. This plant was a prototype for the design of the metal reduction factory at Springfields. The process is essentially based on the calcium reduction of uranium tetrafluoride prepared by converting pure ammonium diuranate to UF_4, reducing in and passing hydrogen fluoride gas through electric furnaces (*3*).

In Belgium a search has been made for a method of preparing UF_4 by using an inexpensive fluorination material, which could be recycled after recovery, would not be toxic, and could be handled easily. The process should not involve highly expensive corrosion-resistant alloys for furnace linings as necessary when one uses hydrofluoric acid gas, and a high yield at the metal reduction should be obtained.

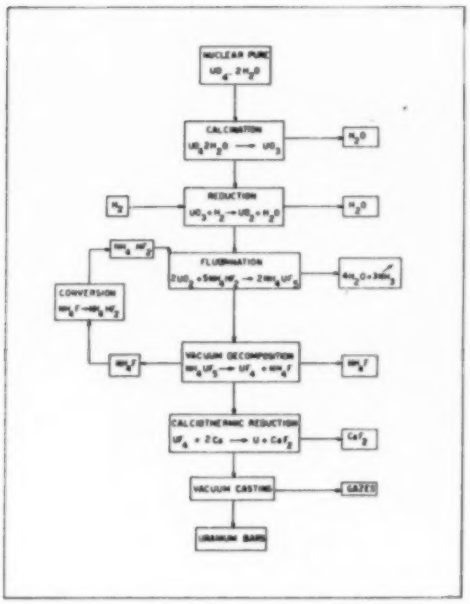
Process for Metal Extraction

The process used for the uranium metal preparation and reduction consists essentially in the calcium reduction of uranium tetrafluoride (*1*). It is detailed in flow sheet of operations (Figure 1).

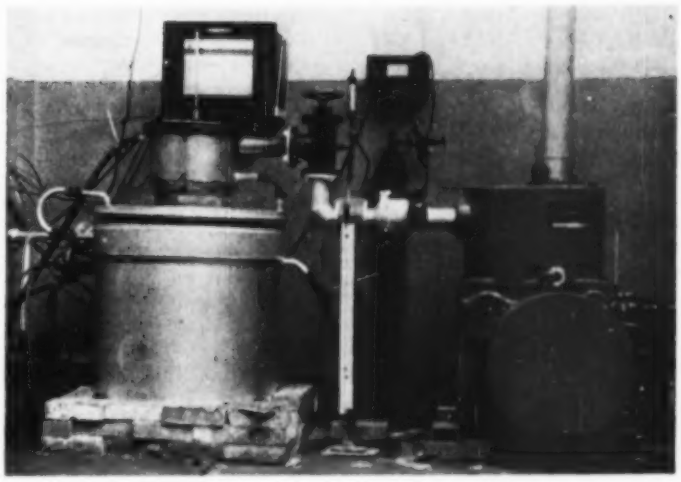
1. CONVERSION OF $UO_4.2H_2O$ TO UO_3

The basic material used in the process of conversion is the nuclear pure oxide $UO_4.2H_2O$ obtained through the precipitation with H_2O_2 of the uranyl nitrate purified by ether extraction. The uranyl nitrate was supplied by the Union Minière du Haut-Katanga, owner of the process for metal extraction since 1952, and the company which treats the uranium concentrates for radium extraction. The $UO_4.2H_2O$ is decomposed into UO_3 by heating to 250° C. for 4 hr. The operation is carried out in a quartz tube furnace.

The author is a consultant, Centre d'Etudes pour les Applications de l'Energie Nucléaire, Brussels, Belgium, and a consultant, Union Minière Du Haut-Katanga.



◀ Fig. 1. Uranium preparation flow sheet.



▲ Fig. 2. Laboratory unit for decomposition of double fluoride.

2. REDUCTION OF UO_3 TO UO_2

The UO_3 is transferred to a nickel (or graphite) tray and reduced in hydrogen at 600° C. for ±4 hr. in an electric furnace. The furnace consists of a horizontal elliptic stainless steel cylinder, 5 ft. long × 6 in. wide, heated externally by a resistant-heating element of Kanthal ribbon. The furnace is hermetically closed on both sides with springs, the sealing is done by rubber gaskets between machined steel plates tightened to the furnace. In case of explosion of the air-hydrogen mixture, the plates work as a security valve.

The temperature of reduction is such that the agglomeration of the oxide is avoided. The hydrogen is of commercial gas-cylinder quality, the flow of which is controlled through normal valve arrangements. The end of the reaction is judged by the change in the appearance of the issuing hydrogen flame; this is blue when containing water vapor from the reduction and whitish on completion of the reaction.

3. FLUORINATION OF UO_2

The fluorination of UO_2 is done with ammonium bifluoride $NH_4.HF_2$, a white solid which does not dissolve, has a low vapor pressure, and can be handled freely since it is not toxic.

The reaction

$$2\,UO_2 + 5\,NH_4.HF_2 \rightarrow 2\,NH_4.UF_5 + 3\,HN_3 + 4\,H_2O$$

is exothermic.

From the previous stage the UO_2 is mixed with the bifluoride plus 20% more than the stoichiometrically required quantity. The crystalline bifluoride powders easily, and mixing the UO_2 and $NH_4.HF_4$ is done in wooden containers to avoid contamination.

The conversion to the double fluoride will take place at room temperature in about 24 hr., although under such conditions the water formed on reduction may be retained. Elimination of water and ammonia is facilitated by reacting UO_2 and $NH_4.HF_2$ at 150° C. At this temperature only 8 hr. are required to effect fluorination. The reaction is carried out in aluminum containers lined with calcium fluoride and heated in an aluminum-lined furnace. The furnace is provided with a loose-fitting condensing tube which carries the water and ammonia of the fluorination reaction to a stack and retains the excess subliming bifluoride.

During fluorination and/or decomposition the formation of UO_2F_2 probably occurs, but does not appear to be significant, judging from UF_4 analyses and metal-reduction efficiencies as shown hereinafter.

4. DECOMPOSITION OF $NH_4.UF_5$ TO UF_4

In the reaction

$$NH_4UF_5 \rightarrow UF_4 + NH_4F$$

the double fluoride $NH_4 \cdot UF_5$ is decomposed to UF_4 under vacuum, as the ammonium fluoride NH_4F is distilled.

Figure 2 reproduces the operation as carried out in the vacuum furnace.

The furnace is a stainless steel cylindrical vessel contained in another outer vessel of mild steel, the annulus between both containing a Kanthal ribbon wire wound. The annulus can be evacuated to a rough vacuum, allowing the use of comparatively thin-walled-furnace cylinders at high temperatures. The vacuum seal is achieved by rubber gaskets between water-cooled machined-steel face plates. The furnace itself carries a water-cooled condensing head contained in the chamber, which is connected to the vacuum system. The double fluoride is laid out on aluminum trays (or graphite) about 2 in. deep lined with calcium fluoride. These trays are suspended on a holder which also acts as cover against NH_4F crystals falling from the upper condenser into the trays. The temperature of the charge is determined by a thermocouple placed in the central part of the vessel.

A heating program for decomposing the double fluoride must be followed. The cycle in Table A has been found satisfactory.

Table A.

	Temperature Range	Time of Heating Hr.	Product of Decomposition
(a)	Room–350	8	NH_3
(b)	350–500	4	NH_4F
(c)	500	4	NH_4F

In stage (a), all remainng NH_3 is pumped off. Stage (b) reduces the nitrogen content to 500 p.p.m. In the last stage hydrogen at about 600 mm. pressure is added to the system to avoid formation of UO_2F_2, and the nitrogen content is reduced to 5 p.p.m.

* Process described in the A.E.R.E. report M/TN 14, from private communication to H. M. Finniston.

The condensed monofluoride NH_4F is easily removed from the condenser by tapping. It can be converted to bifluoride by dissolving in water and recrystallizing the salt. The tetrafluoride is obtained as a powder of ±100 mesh. It does not agglomerate into lumps, and does not adhere to the lining of the trays. Kept in glass bottles, it has stoppers but is not sealed.

5. REDUCTION OF UF_4 WITH CALCIUM

The reduction of UF_4 carried out in the reactor (Figure 3) is shown in process of reaction. This reduction

$$UF_4 + 2\,Ca \rightarrow U + 2\,CaF_2 + 140\ K\ cal.$$

is highly exothermic and the heat emitted from the reaction is sufficient to melt the uranium metal and CaF slag obtained at temperatures as high as 1,800° C.

The reactor consists of an outer welded mild steel flanged vessel (approximately 2-ft. diam. × 3 ft. 6 in. high) lined with CaF_2. The vessel (aluminized externally) has a heating element set on the inside (nichrome wire is used) for drying the lining before charging. The reactor is built up from a preformed sintered collecting crucible of CaF_2. This crucible is ⅓ in. thick and of the same design and dimensions as the sintered alumina crucible used for casting.

All of this care in reactor preparations ensures that the uranium billet, produced by the reduction will, without further treatment after reduction, slip easily into the alumina melting crucible of the casting furnace. Figure 4 illustrates the external appearance and dimensions of the crucible (in millimeters) The internal dimensions and tapered shape can be judged from the ingot shown. The heating of the internal stainless steel container enables a careful drying of the CaF_2 lining. This lining is made by tamping CaF_2 powder with wooden tamper tools between the outer stainless steel container and an aluminum former. A top view of the reactor after lining is reproduced in Figure 5. The reactor carries a mild steel-hinged lid to seal the top. This lid carries an inlet pipe to a mechanical pump and to an argon container. The latter can be noted in Figure 3 (left-hand hole) and consists of a number of motor-car inner tubes joined to a common delivery tube. This "gas-holder" is loaded with weights.

In the reduction process the sequence of operations is as follows.

The reactor lid is dropped, the vessel is brought to a rough vacuum (1-mm. Hg), and the whole is then dried at 200° C. for 24 hr. under vacuum.

The calcium for reduction is machined from distilled calcium blocks obtained from aluminum reduced lime. These turnings are about 2 cm. × 1 cm. × 1 mm.

The UF_4 and 15% more than the stoichiometric proportion of calcium chips required, are mixed by shaking in a bottle. The full charge (±60 lb.) is set in several batches to load the reactor. The charge is ignited with open lid and ignition is effected either with a magnesium ribbon or by playing a torch on the surface.

After the reaction (Figure 6) is over, the lid is closed, the vessel evacuated and the argon holder reconnected to the hot system. The exclusion of moisture and air at all stages of the reaction improves separation of slags and metal and gives a billet with cleaner surface for subsequent operations. To discharge the reactor, one withdraws the crucible with its ingot out of the reactor, and the wall lining collapses to powder. A hard skin of fluoride is formed on the surface of the tamped lining, but this is easily broken. The broken (powder) lining is sucked into a vacuum cleaner and reused. The CaF_2 sintered collecting crucible lasts for one reaction only. The

▲ Fig. 3. Reactor for reduction of UF_4 with calcium.

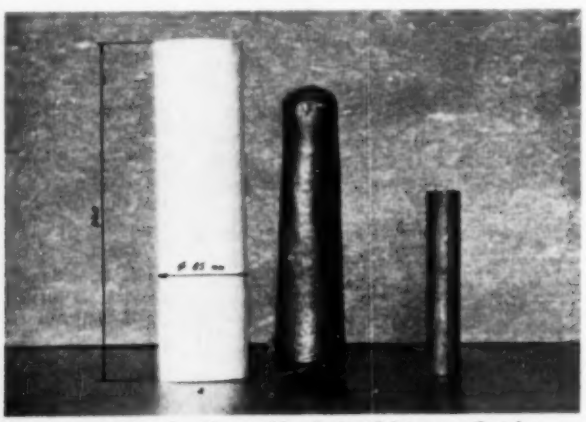


Fig. 4. a. Calcium fluoride crucible. b. Metal ingot. c. Cast bar.

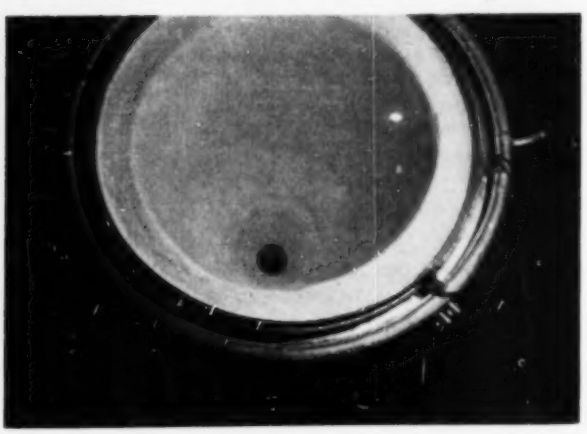


Fig. 5. Top view of lined reactor. ►

Fig. 6. Reactor in process of reaction.

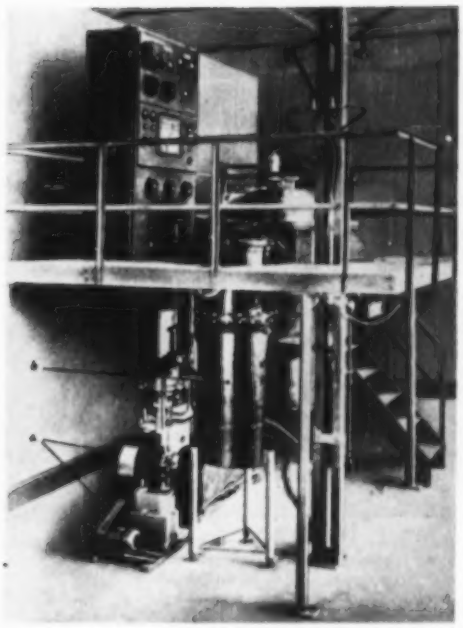


Fig. 7. Vacuum melting and casting furnace.

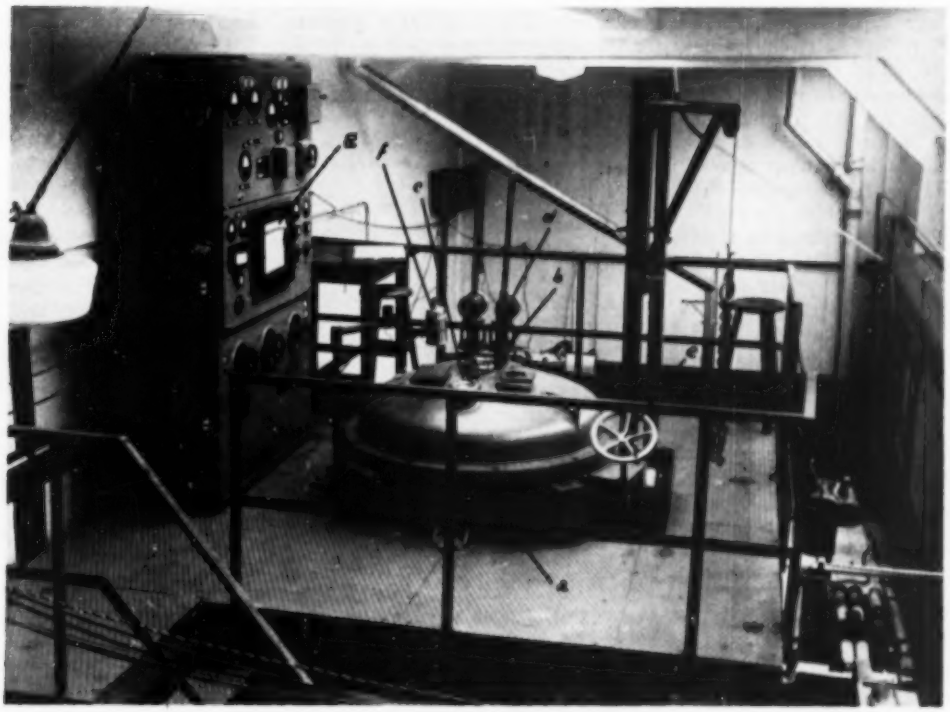


Fig. 8. Top view vacuum furnace.

slag separates easily from the top of the uranium metal billet (see Figure 4).

Yields to this date have been consistently more than 98.5% and in general no significant ejection has been noted during reactions; no blow-outs or misfires have been experienced. The nuclear purity of the metal is found to be of high quality.

6. METAL CASTING AND FABRICATION

The reactor billet is degassed, homogenized and fabricated to the required shape—in this case, bars of 1-in. diam. and up to 3 ft. long, by vacuum melting and casting in preheated graphite molds. The vacuum melting and tilting furnace is shown in Figure 7. Vacuum is obtained through a 150 cu.m.-25 cu.m./hour displacement capacity Leybold pump combination (7a), an oil diffusion pump (7b) and the necessary accessories. The diffusion pump is of 65-cm. diam. and operates on silicone oil. It pumps 2,500 l./sec. at 0.001 mm. Hg.

The melting and casting units illustrated in Figure 8, top view of furnace, are all contained in a welded stainless

Fig. 9. Longitudinal section of cast uranium bar, polarized light x 100.

ANALYSES, PPM			
Chemical	C - 40		
	N - 7		
	O - 16		
Spectrographic			
	B < 0.2	K < 10	
	Fe - 28	Mg < 5	
	Mn - 8	Ag ≤ 0.5	
	Al < 20	Cr < 5	
	Si - 10	Pb < 1	
	Ni < 5	Mo < 1	
	Cu - 3		
As, Ba, Bi, Cd, Co, Cs, Ge, In, Rb, Sb, Su, Cb, Ga, Hf, Pd, Ta, Ti, V, Zr not detected.			

Fig. 10. Typical analysis of cast uranium metal.

steel vessel (8a) with water-cooled annulus. The vessel carries a flanged curved top of similar construction with various openings and devices. These allow surveying the melt (8b), the casting and the molds (8c), removing the slag film on the molten metal (8d), tilting the furnace (and crucible) at casting (8e). The temperature of the melt is determined by both an optical pyrometer (8f) and thermocouples; the temperature of the graphite (or stainless steel) molds is determined by thermocouples and recorded (8g). The slag is removed from the top surface of the molten uranium by inserting a cold graphite rod held just above the liquid when idle. The oxide scum sticks to the cold graphite rod, the movement of the graphite skimmer is obtained by bellows (8d).

The uranium is melted in graphite or sintered alumina crucibles identical in shape and dimensions to the CaF_2 collecting crucible of the reduction reactor. Heating is done either by a molybdenum resistance winding, coiled on an alumina tube or by induction heating of the graphite crucible. Underneath the crucible and furnace a catchpot of graphite in the form of a tray is placed to retain any metal which may run out because of the failure of a crucible.

When high density metal of high purity and containing no carbon is needed, uranium is melted in an alumina crucible. The metal (20 kg.) is melted and ready to cast in four hours. The power input is 10 kw. The vacuum before casting is less than 1μ (actually 0.5μ at 1,400° C.). On casting, the vacuum falls immediately to about 50μ, but subsequently rebounds to about 1μ. The temperature of casting is 1,250° C. The alumina crucibles can be used for twenty casts and show no sign of erosion or chemical interaction at the casting temperature. The molds are of graphite (or stainless steel) and their life is indeterminate. The finish of the cast metal depends on the surface finish of the mold.

Product

Obtained from the melting furnace, the uranium bars have been tested for thermal neutron absorption in both British and American thermal reactors. The metal can be considered excellent for its thermal neutron absorption. The average Rockwell B (1/16-in., 100-kg. ball) hardness is 87. The metal can be rolled into sheets, and ingots can be either extruded or rolled. The cast metal has a variable and large grain diameter (Figure 9). The high value of the average density—namely, 19.02 is probably due to the low carbon and nitrogen content.

A typical analysis of the cast uranium metal is shown in Figure 10.

Conclusions

In conclusion it can be stated that the basic principles of the present laboratory practice on a 20-kg. scale are applicable to an industrial production level. Planning on large-scale production is being directed toward continuous rather than batch processing by adapting existing industrial plants which perform similar operations, rather than by adopting or developing new plants.

Acknowledgment

The author wishes to express his appreciation to Professor C. Decroly for his advice and encouragement during the early investigations. He also acknowledges the United States Atomic Energy Commission and the Atomic Energy Research Establishment of Harwell for the pile tests and the analyses, and also the Union Minière du Haut-Katanga, supplier of the uranium nitrate.

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Thorium
and rare earths from monazite

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The practical development of nuclear power depends on reliable sources of fuels. Thorium is an important source, not that it is directly usable as derived into metallic form from its natural state, but because it can be made into a fissionable form through irradiation. Thorium occurs in nature along with rare earth metals, and so the history of the development of separation techniques includes successful production of these other metals. This paper describes one of these processes, and exemplifies the nature of the problems and the chemical engineering techniques used in their solution.

Interest in thorium and the rare earths has increased markedly during the past ten years, stimulated by developments in atomic energy and in metallurgical fields. Therefore, economical methods of recovering these metals from their ores have attracted attention. Monazite sand is one of the most important sources of these elements. Chemically it contains principally phosphates of the rare earths and thorium. The best known deposits are the beach sands of Brazil and India, but there is some monazite in Florida and Idaho and in other parts of the United States. The sands are upgraded by ore-dressing methods to produce the concentrates which are processed chemically.

This paper describes a process developed for recovering thorium and rare earths from monazite-sand concentrates. It is believed that this process offers several advantages over the conventional sulfuric acid process used by the rare earths industry in the United States (*4*), which consists of digestion of the sand with concentrated sulfuric acid, followed by dissolution of the digestion products in water (*3*). In that process the sand is satisfactorily decomposed, but the resulting solution contains nearly all of the phosphate contained in the sand, the presence of which seriously complicates subsequent separation and purification of the thorium and rare earths.

The process which has been developed as a result of the present investigation involves the following operations:

1. Reaction of the monazite sand with a hot concentrated aqueous solution of sodium hydroxide, which converts the metal phosphates of the sand to hydrous metal oxides and trisodium phosphate.

2. Separation of the hydrous metal oxides from the dissolved sodium phosphate and excess sodium hydroxide.

3. Dissolution of the hydrous metal oxides in hydrochloric acid.

4. Precipitation of a thorium product by partial neutralization of the acid solution.

5. Subsequent precipitation of a high-grade rare earth hydroxide product by further neutralization of the chloride solution.

This process was carried out first on a small scale in the laboratory and subsequently on a larger scale (10 lb. of sand/batch) in pilot-plant equipment.

According to reports (*2*), a plant was put in operation in India during 1952 for the processing of 1,500 tons of monazite/year. Although details of the process are not available, it appears that a caustic soda treatment is being used, since mention is made of the production of by-product trisodium phosphate in appreciable quantities.

Description of Monazite Sand

Monazite sand is derived from the weathering of granites, gneisses, and pegmatites, in which it occurs in concentrations up to 0.1%. It is concentrated into beach and dune deposits by the action of wind and water. Ilmenite, zircon, rutile, quartz and other minerals usually are found with it. By artificial methods of separation, a fraction of almost pure monazite may be concentrated from such sands.

The mineral monazite is honey yellow to brown in color. The grains have a resinous luster, and range from subtranslucent to opaque. Its specific gravity ranges from 4.9 to 5.3, and its hardness from 5.0 to 5.5 (Moh). It is brittle, uneven in fracture, and the separate grains are usually rounded. Primarily composed of rare earth phosphates, it contains, along with numerous other minor constituents, varying amounts of thorium and uranium. Thorium oxide content may be as high as 10%, and uranium oxide (U_3O_8) as high as 1%. Compositions of typical monazite concentrates analyzed are shown in Table 1. Most of the experimental work was carried out with the Brazilian sand.

Table 1.—Composition of Monazite Sand Concentrates

Constituent	Composition, per cent		
	Brazilian	Indian	Domestic[1]
ThO_2	6.5	9.8	3.1
U_3O_8	0.17	0.29	0.47
$(RE)_2O_3$	59.2[2]	58.6[2]	40.7[2]
Ce_2O_3	26.8	27.2	.....
P_2O_5	26.0	30.1	19.3
Fe_2O_3	0.51	0.80	4.47
TiO_2	1.75	0.40	.....
SiO_2	2.2	1.7	8.3

[1] Florida sand containing about 70% monazite.

[2] Includes Ce_2O_3.

Laboratory Studies

After carrying out preliminary studies on various methods of decomposing monazite sand, including treatment with sulfuric acid, it was concluded that removal of the phosphate by caustic soda treatment offered the most promise. Such a process would permit separation of the phosphate from the rare earths and

thorium at an early stage and would yield a by-product trisodium phosphate.

Fusion of monazite with caustic soda has been described previously (*1*). Repetition of this method resulted in satisfactory decomposition of the monazite, but the reaction product was a hard, solid mass, difficult to handle. Further work showed that the treatment of monazite concentrates at elevated temperatures with a concentrated aqueous solution of sodium hydroxide is a satisfactory method of opening up the monazite mineral for further processing. This treatment can be carried out at atmospheric pressure. The resulting aqueous mixture can be readily processed.

VARIABLES IN CAUSTIC SODA PROCESS

In order to establish optimum operating conditions for the subsequent larger scale studies, several variables were investigated.

Effect of Sodium Hydroxide to Sand Ratio

Increasing the weight ratio of caustic soda to monazite sand at constant temperature increased the amount of decomposition of the sand, but the rate of increase became much less marked above a ratio of 3. In actual practice a ratio of 1.5 was found satisfactory.

Effect of Reaction Time

The decomposition of the sand increased with reaction time up to about 3 hr.

Effect of Temperature of Reaction

In the early laboratory studies with relatively coarse monazite sand, best results were obtained at about 390° F. However, later work with more finely ground sand showed that reaction temperatures below 300° F. were more satisfactory, as indicated below. Above 390° F. the reaction mass became too dry and thick to handle conveniently. At atmospheric pressure the effects of temperature and concentration of caustic soda were not readily separable, since, as the temperature increased, water was lost by evaporation and the sodium hydroxide concentration increased.

Effect of Particle Size

As expected, the rate of reaction increased rapidly as the particle size of the sand decreased. By reducing the sand to 100% −325 mesh, the severity of the reaction conditions required to decompose essentially all of the sand was reduced. Good results were obtained with −325-mesh material using a sodium hydroxide to sand ratio of 1.5, an initial sodium hydroxide concentration of about 45%, a reaction temperature of 280° F., and a reaction time of 2 to 3 hr. Under these conditions the attack on the monazite was nearly quantitative.

DILUTION AND FILTRATION OF CAUSTIC SODA REACTION SLURRY

After the sand had been reacted with caustic soda, the reaction mixture was diluted with water to about 30% sodium hydroxide, while maintaining a temperature of approximately 212° F. Under these conditions the trisodium phosphate remained in solution. The slurry was filtered at 180-200° F. to remove the hydrous oxides of thorium and the rare earths from the sodium hydroxide-sodium phosphate solution. The filtered oxides were washed twice with volumes equal to those of the diluted reaction slurry, which reduced the soluble phosphate content of the cake to approximately 0.4% P_2O_5.

DISSOLUTION OF METAL OXIDES IN ACID

In order to prepare a solution from which the thorium and uranium could be selectively precipitated by neutralization, several acids were investigated for dissolving the above-mentioned hydrous oxides. It was found that the reaction conditions during the caustic soda treatment influenced the solubility of the oxides. At the higher reaction temperatures (390° F.) the thorium was converted into a refractory material which was difficult to dissolve in mineral acids. However, after treatment at the preferred caustic soda reaction temperature of 280° F., the washed oxides dissolved readily in nitric, hydrochloric, or sulfuric acid, leaving only a residue of about 2% of the weight of the monazite sand. This residue consisted of a small amount of unreacted monazite and a larger amount of rutile, an impurity in the sand.

Best results were obtained when hydrochloric was used as the dissolving acid. The oxides from 20 g. of monazite-sand concentrates could be dissolved easily in 44 ml. of hot (160° F.) 37% hydrochloric acid. The resulting solution was found to contain more than 99.5% of the thorium and rare earths present in the original monazite.

Dissolution of the hydrous metal oxides in strong (62%) sulfuric acid at 160° F. was comparable to dissolution in hydrochloric acid. However, selective precipitation did not proceed as satisfactorily from the sulfate solution as from the chloride solution.

SEPARATION OF THORIUM FROM RARE EARTHS BY SELECTIVE PRECIPITATION

Laboratory studies showed that the thorium could be selectively precipitated from the chloride solution by partial neutralization with ammonium hydroxide or sodium hydroxide. By raising the *p*H of the solution to 5.8-6.0, more than 99% of the thorium and uranium precipitated, and only 2 to 3% of the rare earths came down. The filtered thorium product required thorough washing to obtain maximum separation from rare earths. Further neutralization of the combined filtrate and washings with sodium hydroxide solution precipitated the rare earths quantitatively. The dried rare-earth product, analyzing 73% rare earths, contained 97-98% of the rare earths present in the original monazite.

RECOVERY OF CAUSTIC SODA AND SEPARATION OF TRISODIUM PHOSPHATE

Since a substantial excess of sodium hydroxide is required for the reaction of monazite sand concentrates with caustic soda, laboratory studies were aimed at finding methods of recovering the excess and recycling it back to the reaction. It was found that if the sand-caustic soda reaction mixture was diluted hot to about 30% NaOH, the trisodium phosphate present in the mixture remained in solution. This permitted separation from the insoluble metal oxides by filtration at 180-200° F.

The filtrate was concentrated by evaporation until the boiling temperature reached 275° F., which approximated a 47% solution of caustic soda. Previous studies showed that solubility of trisodium phosphate in sodium hydroxide becomes quite low (below 1.3%) at sodium hydroxide concentrations above about 36% by weight, and the solubility varies only slightly with temperature at these concentrations. In evaporating the above solution to a boiling point of 275° F., dense crystals of trisodium phosphate crystallized out and could be separated by hot filtration. In this case 99% of the trisodium phosphate was removed. The remaining caustic soda solution was suitable for recycling, but, in order to prevent build-up of silicate, about half the caustic was used for neutralization of the chloride solution to precipitate thorium and the rare earths.

Larger Scale Studies

In order to determine the operability of the process on a larger scale, a series

of runs in pilot-plant equipment was carried out. The flow sheet of the process which was developed as a result is shown in Figure 1.

GRINDING OF MONAZITE SAND CONCENTRATES

For the process under investigation it was necessary to have a finely ground monazite. The sand is hard (5.5 Moh) but brittle, and was reduced to 96.5% −325 mesh (100% −200 mesh) by wet ball-milling for 8 hr. in a 7-gal. Abbé jar mill using 1- to 2-in. flint pebbles. A charge consisting of 16.5 lb. of sand, 2 gal. of water, and 47.5 lb. of pebbles was used with a rotation speed of 58 rev./min. In a large installation continuous wet classifying with return of oversize would be desirable. Since the discharge from the mill contained excessive amounts of water, it was allowed to settle, and supernatant water was removed until the sand-water mixture contained 39% H_2O.

REACTION OF MONAZITE WITH CAUSTIC SODA

The equipment used is pictured in Figure 2. The stainless steel reaction vessel had a capacity of about 10 gal., and was fitted with external electric heaters, a variable-speed agitator, a flush-bottom valve, and a thermocouple. Fed to the vessel at the start of a run were the sand slurry, commercial anhydrous caustic soda, water, and recovered caustic soda solution recycled from a later step. In a commercial plant the water and anhydrous caustic soda would be fed simultaneously as liquid caustic soda containing 73% NaOH. The amounts of materials charged were controlled so that initially the following conditions were obtained in the reactor:

Sand charge	10 lb. (dry basis)
Ratio of NaOH to sand	1.5
Ratio of water to sand	1.7

This mixture was then heated to a temperature of 280° F. and maintained there, with moderate agitation, for 3 hr. This was sufficient time for the sand to react completely with the caustic soda.

After complete reaction the mixture was diluted with a wash solution from a later step to keep the trisodium phosphate in solution when the temperature was lowered. The slurry was digested at 220° F. for 1 hr. to facilitate later filtration. Its volume at this time was about 0.7 gal./lb. of sand charged. After digestion the slurry was filtered.

Filtration of Reaction Slurry and Washing of Hydrous Oxide Cake

Filtration of the digested slurry to remove the hydrous oxides from the solution of trisodium phosphate and excess caustic soda was performed at a temperature of 180° F. under pressure. The steel filter consisted of one horizontal plate with a steam-jacketed chamber. The filter medium was a piece of 500-by-28-mesh Monel wire cloth. The slurry was delivered by a centrifugal pump to the filter and maintained at a gauge pressure of about 60 lb./sq.in. The solids were almost granular in nature, and filtered easily.

After the filtrate became clear, it was sent to the evaporator for concentration and removal of trisodium phosphate. At completion of filtration the hydrous oxide cake was washed in the filter with water until practically all the soluble elements in the cake were removed. The wash solution was recovered and recycled to a subsequent reaction for its dilution prior to digestion. The cake was blown dry with compressed air and sent on to the acid-dissolution vessel. During blowing some of the cerous oxide in the cake was oxidized to ceric oxide.

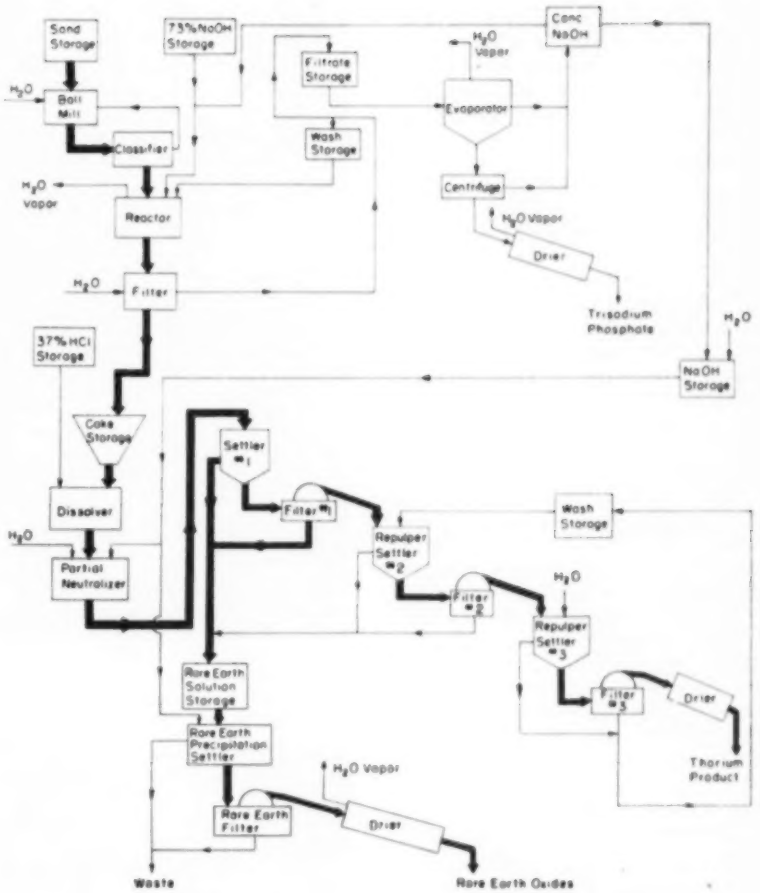

Fig. 1. Flow sheet for the recovery of thorium and rare earths from monazite.

At this point the hydrous oxide cake contained the following quantities of the constituents charged in the monazite sand:

Constituent	Per Cent Accounted for in Hydrous Oxide Cake
Uranium	96.9
Thorium	100
Rare earths	100
Phosphorus	0.3

Recovery of Excess Caustic Soda and Trisodium Phosphate

The filtrate from the reaction contained unchanged about two thirds of the caustic soda charged. The other third had been converted to trisodium phosphate. Both materials remained dissolved in the filtrate, provided its temperature did not fall below about 140° F. Below this temperature a trisodium phosphate hydrate separated incompletely from the solution.

In order to achieve nearly complete separation of the phosphate, it was

necessary to concentrate the filtrate by evaporation. At the same time the caustic soda liquor remaining after removal of phosphate was prepared for recycling to a later reaction with monazite sand.

Evaporation was carried out in an open steel kettle, steam jacketed and fitted with an agitator and thermocouple. The filtrate was evaporated until its boiling point reached 275° F., corresponding to a sodium hydroxide concentration of about 47%. At this concentration, 99% of the trisodium phosphate had crystallized out of solution, and could be removed by filtration. After filtration the caustic soda liquor was ready for use either in sand reactions, or for later neutralization of acid solutions of hydrous oxide cake. The trisodium phosphate crystals were dried, and constituted a by-product of the process. Typical compositions of the dried crystals and liquor are shown in Table 2. The trisodium phosphate product could easily be upgraded by recrystallization, or neutralization of the sodium hydroxide with phosphoric acid.

The recovered caustic soda liquor was divided into two parts: 45% of it was recycled to the sand reaction, and 55% was diluted with water and used for neutralization purposes later in the process.

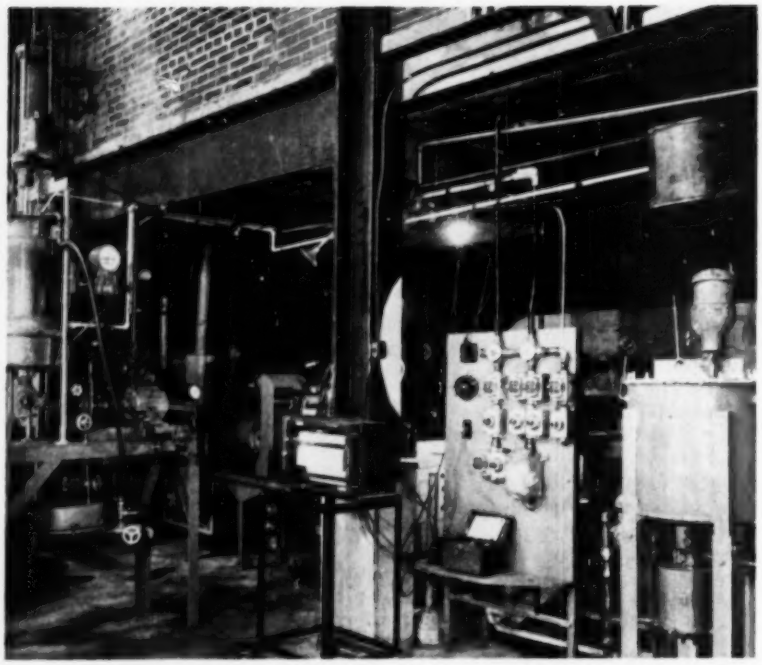

Fig. 2. Production unit equipment for the reaction of monazite sand with caustic soda solution (left) and the recovery of excess caustic soda and trisodium phosphate (right). In the center is shown the Brown recording potentiometer, and to its right, the electrical control panel, both of which were used with the reaction unit.

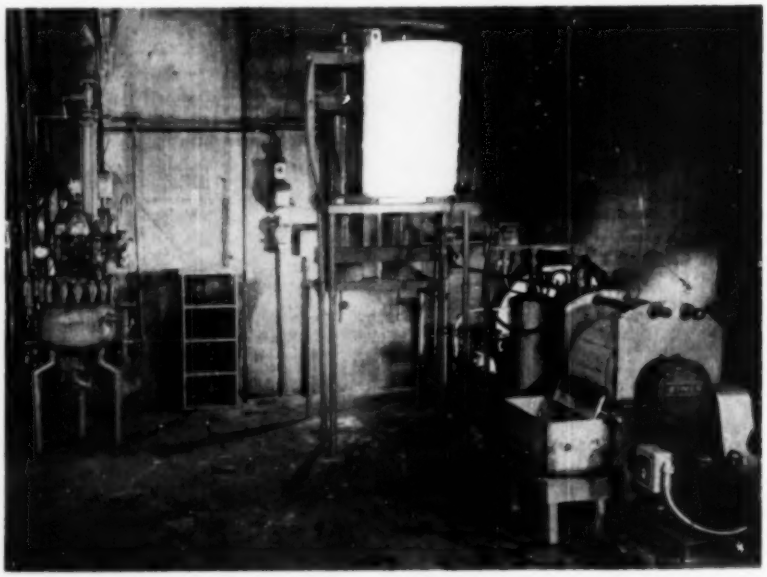

Fig. 3. Pfaudler glass-lined unit for dissolution of hydrous oxide cake in hydrochloric acid (left) and Eimco rotary drum vacuum filter (right).

Dissolution of Hydrous Oxide Cake in Hydrochloric Acid

The hydrous oxide cake was next placed in a 5-gal. steam-jacketed Pfaudler kettle fitted with a flush-bottom valve, agitator, and thermocouple (Figure 3). To it was added 37% hydrochloric acid, 1.5 lb. of acid/lb. of sand. The mixture was heated at 175° F. for 1 hr. This was sufficient time to allow complete dissolution of all essential material in the cake. Presence of ceric oxide in the cake at this point caused evolution of chlorine gas from the mixture. A portion of the cake, consisting mostly of unreacted rutile and zircon, remained insoluble in the acid and was carried along as suspended solid matter. This avoided the filtration of the hydrochloric acid solution.

The acid solution was then transferred to the neutralization vessel, and diluted with water. Concentration of a typical solution after dilution is shown in Table 3.

Table 2.—Typical Composition of Dried Trisodium Phosphate Crystals and Recovered Caustic Soda Liquor

Constituent	Composition, per cent	
	Crystals	Liquor
Na_3PO_4	86.8	0.53
Na_2SiO_3	0.39	1.48
NaOH	10.2	47.4

Separation of Thorium and Uranium by Selective Precipitation from Hydrochloric Acid Solution with Sodium Hydroxide

The diluted hydrochloric acid solution of hydrous oxide cake was partially neutralized by the addition of a sodium hydroxide solution. This operation was carried out at room temperature in an

Table 3.—Composition of Typical Hydrochloric Acid Solution of Hydrous Oxide Cake After Addition of Dilution Water

Constituent	Concentration, grams per liter
U	0.21
Th	8.4
R.E.	74
Fe	0.85
Ti	1.3
P	0.05
Cl	24

open stoneware vessel fitted with a high-speed agitator.

The sodium hydroxide solution used was a portion of the caustic soda liquor recovered from the evaporation step, diluted with water. It was added to the acid solution until an equilibrium *p*H of about 5.8 was reached, as measured with a glass-calomel electrode system and a Beckman meter. The dilution of the caustic soda solution and of the acid solution with water was to make the precipitation at this point more nearly homogeneous. The slurry formed was quite fluid, and could be agitated easily. The effect of high localized *p*H during precipitation was minimized.

At *p*H 5.8, all thorium and uranium were precipitated, and about 3% of the total amount of rare earths. The balance of the rare earths remained in solution as chlorides. The distribution of constituents between solution and precipitate at *p*H 5.8 is shown in Table 4.

Table 4.—Distribution of Constituents Between Solution and Precipitate After Selective Precipitation of Thorium and Uranium at *p*H 5.8

Constituent	Fraction, per cent of total	
	In Solution	In Precipitate
U	0.7	99.3
Th	0.3	99.7
R.E.	97.7	2.3
Fe	0	100
Ti	0	100
P	0	100
Cl	99.9	0.1

After neutralization the slurry was allowed to settle prior to decantation and filtration in order to separate the solids from the solution.

Sedimentation, Filtration of Slurry, Repulping and Washing of Thorium-Uranium Cake

The high degree of separation of constituents shown in Table 4 could not be realized unless occluded and retained liquor was efficiently removed from the solids by washing. For this purpose a series of three filtrations and two washings was set up. Before each filtration, the slurry was settled and as much supernatant liquor as possible removed by decantation. After the first two filtrations, the cake was repulped and vigorously stirred in water. The filtrations were performed with an Eimco rotary drum vacuum filter, covered with heavy cotton duck cloth, and operated at 15 in. of Hg vacuum (Figure 3). The cake was continuously removed by a scraper, and repulped for the next filtration. After the third filtration, the cake was dried. The flow sheet (Figure 1) clearly shows these operations.

The initial slurry was settled, decanted, and filtered. The decantate and filtrate were combined, and the wet cake was repulped in the combined decantate and filtrate from the third filtration cycle. The repulped slurry was settled again, decanted, and filtered. The decantate and filtrate were combined with the liquors from the first filtration. The wet cake was repulped in water containing 0.5% of sodium nitrate, settled, decanted, and filtered. The final wet cake was dried, the decantates and filtrates were combined for subsequent recovery of rare earths.

In general one half to two thirds of the total liquor could be separated clear from the settled slurry by decantation. The thick slurry remaining yielded, on filtration, a cake containing about 20% dry solids, which included all the material insoluble in acid, along with the thorium-uranium precipitate. The addition of sodium nitrate to the wash water was to improve the flocculating and settling characteristics of the solids. A brief heating of the slurries further hastened their settling. The solids discharged from the filter were thixotropic and gelatinous in nature, and filtered slowly. Pressure filtration could not be used to good advantage because the solids tended to extrude into and through the filter medium at high filtration pressures.

The final wet cake was oven dried at 220° F. to constant weight. A typical analysis of such a cake is given in Table 5.

A much purer thorium product could be obtained from this cake by redissolving in a mineral acid, filtering from acid-insoluble material (largely silica, rutile, and unreacted monazite), and reprecipitating by addition of ammonia.

Table 5.—Composition of Typical Thorium-Uranium Cake After Washing and Drying

Constituent	Composition, per cent
U	0.74
Th	36.4
R.E.	7.45
Fe	2.21
Ti	6.73
Si	4.47
P	0.44
Cl	0.36
Acid insoluble	23

Table 6.—Composition of a Typical Dried Rare-Earth Cake

Constituent	Composition, weight per cent
U[1]	0.005
Th	0.05
R.E.	73
Fe[1]	0.02
Si[1]	0.4
P[1]	0.1
Cl	7.9

[1] These constituents introduced partially with recovered caustic liquor used to precipitate the rare-earth hydroxide.

Recovery of Rare Earth Hydroxides

The combined decantates and filtrates from the separation and washing of the selectively precipitated thorium-uranium cake contained about 97% of the rare earths as chlorides in solution. They were isolated by precipitation with sodium hydroxide solution recovered during the evaporation step. About 62% of the unrecycled recovered caustic soda liquor was used for this step. The other 38% was used for the selective precipitation of thorium and uranium.

After precipitation of the rare earth hydroxides, the resulting slurry was filtered and the hydroxide cake dried. The composition of a typical, dried, rare earth cake is given in Table 6. The filtrate from this separation contained only sodium chloride and sodium hydroxide in small quantities and was discarded.

Acknowledgment

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Materials for nuclear reactors

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Materials for nuclear reactors are selected on a basis quite different from that for most chemical engineering equipment items. Some materials are chosen because they are readily penetrated by neutrons, others because they protect against penetration. Still others are required to have a certain degree of neutron speed-reducing quality. All are more or less subject to changes brought about by neutron bombardment and other effects of exposure to radiant energy, even to the point of deformation or transmutation into highly radioactive elements. This paper summarizes materials choices for typical reactors.

The design of nuclear reactors to be used as sources of heat for the production of economic electric power is dependent upon many factors. One of the most important is the choice of materials of construction. It is the purpose of this paper to list a few of the materials which may be used in building nuclear reactors and to discuss briefly some of the reasons for choice of specific items.

The nuclear reactor is the central device or tool of the entire nuclear-energy program. Essentially it is a device for transforming the potential energy of fission of U^{235} and plutonium into useful heat. The conversion of nonfissionable thorium and the nonfissionable isotope of uranium, U^{238}, into the fissionable isotopes of U^{233} and Pu^{239} may be carried out with the production of useful heat.

Development of reactors for power production has gone forward rapidly during the past few years. Perhaps, ninety-five per cent of the basic facts necessary for design of nuclear plants are known. The advancement has reached a stage at which small amounts of electric energy have been produced from heat generated in two different types of reactors. Several types of reactors give promise of producing electric power at costs equal to or less than many plants in the United States now using coal or oil. Obviously, costs of operation and potential lifetime for the reactors can be obtained only through experience with full-scale plants. Normal industrial lifetime for nuclear power plants is expected.

A nuclear reactor contains several different materials for various purposes, including fuel, fertile materials, fuel covering or cladding, coolants, moderators, control devices, structural, and shielding materials. In addition, means for loading and unloading fuel assemblies, handling and controlling the coolant, neutron and power level sensing instruments, and thermocouples, are always provided. Since several different materials can be used for each of the just-mentioned purposes, it is obvious that there are many possible variations of nuclear reactors. Practical considerations reduce these to a reasonable number and cost analyses reduce them to only a few reactor types of economic interest. A moderator is a low atomic-weight material placed in a reactor to slow down the neutrons. The use of slow neutrons permits a chain reaction to proceed in natural uranium since fissionable material absorbs slow neutrons more readily than fast neutrons. If moderator materials are present, the neutrons are slowed to thermal energies and the reactor is called a thermal reactor. If no moderating material is present, the neutrons on the average are utilized at high energies and the reactor is called a fast reactor. While a few kilograms of pure fissionable material will maintain a chain reaction in a thermal reactor, many kilograms of highly enriched material are required for a fast power reactor. If the fuel is held in plates or rods, it is a heterogeneous reactor; if the fuel is dissolved in the coolant, it is a homogeneous reactor. Fast and thermal reactors may be either heterogeneous or homogeneous. Thus, there are four general types with variations, such as fluid fuels in heterogeneous reactor fuel elements.

Uranium, thorium, and many materials considered as fuel cladding and structural parts of reactors are metals high in the electromotive series with a great affinity for oxygen. This is also true of the moderator beryllium and the coolant sodium. Water itself may be considered a most active material.

In addition to cost, selection of materials depends on availability, neutron properties, such as absorption and scattering of neutrons, corrosion resistance, heat transfer, tensile strength and creep resistance at high temperature, workability and ease of welding, resistance to radiation damage and to dimensional changes due to irradiation, and radioactivity build-up in the material itself. Of these, the neutron properties and corrosion resistance are by far the most important. Unfortunately, the common metals, with the exception of magnesium and aluminum, have too high neutron cross-section or absorption rates for use in thermal reactors. For this reason the Atomic Energy Commission through its contractors and national laboratories has had to develop zirconium as a cladding or structural material and beryllium and beryllium oxide as moderator materials. Considerable development effort has been spent on aluminum, stainless steels, and graphite in addition to the work on uranium, thorium, and the metals just referred to. (See Table 1.)

Thermal Reactors

Materials used in thermal reactors must be particularly free of elements which strongly absorb thermal neutrons such as boron, lithium, cadmium, and cobalt. In addition, cobalt be-

Table 1.—Properties of Heterogeneous Reactor Materials

Material	Use	Thermal Cross Sections, Barns: Fission	Non-Fission Capture	Melting Point, °C.	Density g./cc.	Tensile Strength Annealed, lb./sq.in.	Approximate Cost
U^{235}	Fuel	.....	.....	1133	19.1	.....	$————
U^{233}	Fuel	575	101	1133	19.1	.....	20/g.*
Pu^{239}	Fuel	664	361	632	19.6	.....	————
U^{238}	Source	0	2.8	1133	19.1	.....	————
Th	Source	0	7.0	1690	11.7	.....	————
Nat. U		4.09	3.5	1133	19.1	.....	$35/lb.†
Al	Clad, structural	.....	0.21	660	2.7	13,000	
Zr	Clad, structural	.....	0.18	1845	6.5	35,000	$15/lb.
347 s.s.	Clad, structural	.....	2.9	~1400	7.8	90,000	————
Be	Moderator	.....	0.009	1315	1.84	45,000	$125/lb.
BeO	Moderator	.....	0.009	.....	2.8	.....	20/lb.
Graphite	Moderator	.....	0.0045	.....	1.52	.....	————
H_2O	Coolant, moderator	.....	0.66	.....	1.00	.....	————
D_2O	Moderator, coolant	.....	0.00092	.....	1.10	.....	$80/lb.†
Na	Coolant	.....	0.50	.....	0.97	.....	
B	Control	.....	750	.....	.....	.....	————
Cd	Control	.....	2400	.....	.....	.....	————

* Public unofficial estimate.
† European estimate.

comes intensely radioactive with a half life so long that time cannot be allowed for its decay in order to carry out maintenance operations.

It is customary to measure the effective collision cross section between a neutron and a nucleus of an atom as an area, numerically, times 10^{-24} sq.cm., or barns designated as σ_a for absorption. This number times the number of nuclei/cc. gives the net absorption of neutrons/cc. designated as Σ_a. For fission cross section σ_f is used and σ_c for nonfission capture. Mathematically, the cross section is given by the equation

$$\Sigma = N\sigma \text{ cm}^{-1}$$

in which N is the number of nuclei/cc. It should be noted that σ_a varies from practically zero for helium up to very high values for such elements as Cd, $\sigma_a = 2400$.

For use in a reactor a material should have a σ_a of a few tenths at most. Materials of low cross section which have high cross-sectional impurities in amounts usually considered negligible may not be useful in reactors. Fortunately carbon and oxygen have low cross sections, σ_a 0.0045 and 0.0009, respectively. Nitrogen, boron, lithium, and cobalt have cross sections of 1.8, 750, 67, and 35, respectively.

Table 2.—Materials for Practical Thermal Power Reactors

Fuel	Moderator	Coolant	Structural & Cladding
Natural U	D_2O, C	D_2O, H_2O	Al, Zr
Slightly enriched U, or U^{235} (U^{235}) in Th	H_2O, C	H_2O, Na	Al, Zr, s.s.
U^{235}	H_2O	H_2O	Al, Zr, s.s.

Source and Fissionable Materials

It will be recalled that natural uranium contains 0.711% U^{235} and 99.3% U^{238} and that thorium consists of Th^{232} only. U^{235} is the only naturally occurring fissionable material or fuel. U^{238} and Th^{232} may be converted into the fissionable materials Pu^{239} and U^{233} by absorption of neutrons in reactors. Actually, the new fissionable materials are not formed directly, but the U^{239} and Th^{233} undergo radioactive transformations or decay processes in a short time to form the fissionable materials. U^{238} and Th^{232} are called source or fertile materials.

Natural uranium may be used in reactors in which the neutron absorption in the moderator, coolant, and structural materials is very low. Slight enrichment of the uranium to something like 1.0 to 1.5% U^{235} makes it useful in additional reactors. The practical reactor systems are indicated in Table 2. A major reduction in cost of production of beryllium would add it to the list of moderators.

The use of fully enriched U^{235} is limited to small reactor systems in which it is not practical to produce new fissionable materials. Such uses include research reactors, small packaged power units, and mobile reactors.

Both U^{238} and Th^{232} have resonance absorption bands through which the neutrons must pass in being moderated or slowed down in thermal reactors. The resonance absorption forms fissionable isotopes but removes enough neutrons so that it is difficult to maintain fissioning process in natural uranium. This has led to clumping the uranium in bars which segregates the moderator and fuel. The use of slight enrichment offsets the resonance absorption without appreciably changing the over-all conversion efficiency. From an engineering viewpoint clumping is beneficial since reasonably sized fuel elements may be used.

Separation of U^{235} from U^{238} is carried out by gaseous diffusion using UF_6 at the K25 plant at Oak Ridge. Soon additional facilities at Paducah and Portsmouth will add tremendously to the production capacity. In order to obtain uranium with a U^{235} content of one per cent or so, it is necessary to remove the material as UF_6 from the diffusion plant at the proper concentration or to blend highly enriched products with natural uranium. Both procedures are costly. The U^{235} may be used in separate fuel elements in the reactor. This has the advantage that the unburned fuel can be recovered readily for reuse and the disadvantages that the U^{235} is not evenly distributed through the reactor and the procedure is expensive. Use of separate fuel elements made from recycled plutonium or U^{233} may prove to be advantageous.

Because of the high cost of U^{235} and the value of fissionable materials as fuels and weapon materials, considerable effort is being expended to improve the

Table 3.—Neutron Production in Fissioning Processes

Isotope	Neutrons Emitted on Fissioning	Fraction Absorbed Without Fission	Net Neutrons Per Thermal Fission
U^{235}	2.50	0.149	2.13
Pu^{239}	3.00	0.352	1.94

efficiency of utilization of U^{235}. Only a part of the U^{235} is removed in the separation plants. The portion fissioned in reactors depends on the design of the reactor and the conversion ratio or the atoms of new fissionable material formed per atom fissioned. If the conversion ratio is 1.0, the amount of fissionable material present in the reactor will remain constant. However, the reactivity of the reactor may change because of other effects.

As the U^{235} is fissioned in natural or slightly enriched uranium, Pu^{239} is formed which adds to and gradually replaces the U^{235}. At the same time fission products build up in the fuel elements. These absorb neutrons and reduce the reactivity. The fission process causes physical changes in the fuel which limit the "burn-up." At this time the fuel elements must be removed from the reactor, fission products separated, fuel re-enriched as necessary, and new fuel elements made up for further use. It is desirable to recycle the Pu^{239} or U^{233} made in the reactor in order to reduce the cost of re-enrichment. Without recycling, the uranium must be separated from the plutonium and fission products, returned to Oak Ridge or elsewhere, and sweetened for reuse; or the discharged uranium may be scrapped.

Fuel data are presented in Table 3.

In all reactors there is some neutron loss to absorption in the coolant, moderator, control system, and structural materials, and some leakage to the outside.

With natural uranium it is difficult to obtain a conversion ratio of 1.0 even though some neutrons are produced in the U^{238} by the fast neutrons prior to their moderation. With U^{233} a conversion ratio of 1.0 or more appears feasible in several types of reactors.

The term conversion is used whenever U^{235} is "burned" and U^{233} or Pu^{239} produced whether there is an increase in the number of fissionable atoms present or not. The term breeding is used to indicate that Pu^{239} or U^{233} is "burned" and the same isotope produced in a larger amount than "burned." When these are "burned" and the conversion ratio is less than one, the term conversion is usually used. Losses in the chemical separation plants and in the fuel element fabrication are frequently included in the calculations of actual breeding gains to be expected.

Since all the fissionable fuels are toxic to the human body, it is necessary that they be handled with extreme care. Table 4 indicates present tolerance limits with information concerning the part of the body involved. All the materials give off alpha particles with various energies. Actually, it is the energy of the particles produced that does the harm, so the damage is proportional to the concentration of the element in the body organ and the energy produced per particle.

One begins to understand the care that must be taken to maintain air free from dusts when it is realized that 1 microcurie of U^{233} weighs 0.1 mg. All these materials form oxide coatings readily. The alpha particles emitted by Pu^{239} apparently break up the oxide and form aerosols. Therefore, all work on Pu^{239} and U^{233} is carried out in isolated boxes or in extremely well-ventilated hoods. The half life (low rate of decay) of natural uranium and thorium is so great that they can be handled in the open if reasonable care is taken during rolling and machining operations.

Since U^{233} is quite unavailable today, U^{235}, either as natural or slightly enriched uranium, is the fuel being considered for initial use.

A thermal reactor can be started using U^{235} as fuel with thorium present and making U^{233} for later use. Plutonium, as it becomes available for use as a fuel, could be used to enrich natural uranium or it could be used in separate fuel elements to increase the reactivity of the reactor. Usually, uranium is used in the metallic form because it has fair thermal conductivity; $k \cong 15$ B.t.u./(hr.)(sq.ft.)(°F/ft.).

The main difficulty with metallic uranium is that it is an anisotropic metal and tends to alter its dimensions because of temperature changes. Uranium oxide fuel elements can be used if provision is made for their low thermal conductivity.

For reactors built to supply small amounts of power, enriched U^{235} will probably be used for many years.

Cladding Materials

Cladding materials have many requirements besides reasonable cost. These include low neutron cross section; high thermal conductivity; reasonable tensile strength and creep resistance; ease of forming by extrusion, rolling, welding, etc.; ready solubility or removability in the chemical separations plant.

The choice of materials is limited to aluminum, zirconium, and their alloys, and possibly stainless steel for special applications.

In respect to heat transfer, zirconium is about equal to stainless steel. It maintains its strength reasonably well at elevated temperatures, dropping from about 35,000 lb./sq.in. at room temperature to about 15,000 lb./sq.in. at 350° C. It is readily formed by normal rolling, extrusion, and welding by shielded arc. Since the oxide is soluble in the metal, welding is readily carried out and sound welds are obtained.

The cost of zirconium, titanium, and

Table 4.—Maximum Permissible Amount of Radioisotope in Total Body and Maximum Permissible Concentration in Air and Water for Continuous Exposure [1]

Isotope	Organ, g.	Microcuries in Total Body	Microcuries /ml. of Water	Microcuries /ml. of Air	G./cu.m. of Air
U, Nat, sol.	Kidneys, 300	0.2	7×10^{-6}	1.7×10^{-11}	
U, Nat, insol.	Lungs, 1,000	0.009	.....	1.7×10^{-11}	
U^{235}, sol.	Bone, 7,000	0.04	1.5×10^{-4}	1×10^{-10}	1×10^{-6}
U^{235}, insol.	Lungs, 1,000	0.008	.....	1.6×10^{-13}	1.6×10^{-9}
Pu^{239}, sol.	Bone, 7,000	0.04	1.5×10^{-6}	2×10^{-12}	3.0×10^{-11}
Pu^{239}, insol.	Lungs, 1,000	0.008	.....	2×10^{-12}	3.0×10^{-11}

[1] NBS Handbook 42, "Safe Handling of Radioactive Isotopes," Supt. of Doc., 15 cents.

tantalum will limit their use until less costly production methods are developed. Zirconium costs about $15.00/lb. in ingot form, but is much more costly in fabricated form.

Moderators

Beryllium and beryllium oxide are excellent moderators because of their good slowing-down properties and low neutron cross section (0.009×10^{24}) sq. cm. Both materials have excellent corrosion resistance to high purity water. Some beryllium is brittle and it is somewhat difficult to work. Beryllium and the oxide are both poisonous when inhaled or ingested even in small amounts. However, it is selective in its attack and only one person in eight is susceptible to the poison and develops berylliosis. In any case, machining and grinding operations must be done on machines mounted in well-ventilated dry boxes. Beryllium is costly, of the order of $100 to $200/lb., but beryllium oxide costs something like $10.00 to $20.00/lb. Both materials are available in pure form.

Graphite is fairly cheap, has low cross section, but it is a relatively poor moderating material. It has the advantage that a water-cooled and graphite moderated reactor fueled with natural uranium will go critical with a slight margin in excess reactivity. However, the reactors must be quite large involving tens of tons of graphite and uranium.

Coolants

Light water, heavy water (D_2O), and sodium appear to be most usable as coolants. Both light and heavy water have the advantages of high heat capacity and both can be used as moderator-coolants. Both have high vapor pressures at high temperatures requiring heavy equipment. As noted previously, heavy water is expensive and, except in boiling reactors, a large volume is outside the reactor at all times where it cannot serve as moderator.

Both H_2O and D_2O are poor in respect to corrosion since both are active materials. The use of mixed bed ion exchange permits ready cleanup of both liquids so the purity of the circulating water can be maintained with less than 1 p.p.m. total solids present. While beneficial to the reactor, this adds a new difficulty since the stainless steel, external to the reactor, undergoes fairly rapid corrosion. As the corrosion products contain cobalt and other materials which may become intensely radioactive, the entire system becomes radioactive as the oxides precipitate out on active surfaces throughout the cooling system. Work on inhibitors to increase the corrosion resistance of stainless steel is underway. The use of inhibitors, in turn causes additional operational difficulties. The ion-exchange beds act as filters and remove most of the corrosion products precipitated in the water.

Both H_2O and D_2O become intensely radioactive because of the (n,p) reaction with O^{16} forming N^{16}. The N^{16} decay process includes the emission of hard gamma rays, 7.5 and 6.1 mev, but the half life of the decay process is short, 7.5 sec. This means that the N^{16} will decay out in a minute or so. However, all piping and pumps must be heavily shielded to protect personnel and electrical instruments during operation.

Sodium has the advantage of high temperatures at low pressures. However, it has appreciable neutron absorption (0.49×10^{-24} sq.cm.) and freezes at low temperatures. It is an active material in respect to reaction with oxygen and water, but quite inert in respect to corrosion of steel, zirconium, or even aluminum. Means have been developed for handling sodium, and it can be readily cleaned. It becomes very radioactive with a half life of 15 hr. This means that several days are required before sodium becomes reasonably low in activity and the system has to be heavily shielded at all times.

Owing to radioactivity all reactor coolant systems must be completely leakproof. This is not too difficult as a rule, but in boiling reactors in which the steam is taken directly from the reactor to the turbine, extra care must be taken to reduce the leakage from the pipes and turbines.

Structural Materials

Aluminum, zirconium, and stainless steel are usually used as the structural materials within the reactor in conjunction with the same materials as cladding materials. Stainless steel has been used largely, external to the reactor, to maintain high purity of the coolants. Though this has been rather costly, it has been justified on the grounds that it is better to have an expensive, but successful, reactor than one in which there is doubt about its continued operation. In future power reactors more common materials doubtlessly will be used.

Shielding Materials

Shields are usually broken up into two parts. First, there is the so-called "thermal" shield. The purpose of the thermal shield is to reduce the neutron level as well as the gamma-ray level to levels about 10^8/(sq.cm.)(sec.) Since many fast neutrons reach the shield without being moderated or slowed down, the shield should contain a large amount of light hydrogen to slow down these neutrons. The shield should also absorb thermal neutrons rapidly without emitting additional gamma rays. At the same time it is desired to absorb as many gamma rays as possible. Therefore, a dense shield is desired. And above all, the shield should be made of cheap materials.

The materials which have been used are hydrogeneous materials such as wood and water combined with boron and iron to absorb the thermal neutrons. Iron absorbs neutrons satisfactorily, but at the same time gammas are emitted. Boron strongly absorbs neutrons without the emission of gamma rays. So the thermal shield consists of alternate layers of water and steel with a thin layer of boron carbide, held in aluminum, placed over the inner steel layer. The energy of the neutron and gamma rays absorbed heats the thermal shield so that it must be cooled. This is simple for a water-iron shield as cooling water can be pumped through the shield.

Outside the thermal shield is the biological shield which reduces the neutron and gamma rays to a tolerable level for humans. As only mass and neutron absorption is needed, ordinary concrete or concrete with a high specific gravity aggregate such as barytes or limonite may be used. Thirteen inches of ordinary concrete reduces the gamma-ray intensity roughly a factor of 10; hence 8 ft. or so of concrete is adequate.

Control Elements

Control rods are built into a reactor to control the power level by absorbing a portion of the neutrons as it is produced. Since about 0.75% of the neutrons are not emitted during fission reactions, but are delayed on an average of about 1 sec., sensing instruments which measure the neutron flux can automatically direct the control system to move the control rods in or out to hold the neutron flux level, and, therefore, the rate of reaction constant. For thermal reactors materials with high cross sections such as cadmium and boron are used.

In reactors fueled with U^{235}, the fuel present "burns out" or fissions rapidly so that it is not economical to control the reactor entirely by addition of poisons such as cadmium. In this case, additional rods known as shim rods are added. These may contain a fairly large per cent of the fuel charge and are drawn into the reactor as needed to maintain the power level constant. In this case control rods of cadmium or boron are used. The control rods are designed to absorb only a small per cent of the neutrons produced.

Fast Heterogeneous Reactors

Fast reactors have the prospect of making 1.0 or more atoms of new fissionable material for

each one fissioned in the process. This is, of course, the reason for the excitement about breeding. Though thermal reactors can use several per cent of the uranium which occurs in nature and possibly all the thorium, losses in manufacturing fuel elements and reprocessing the irradiated fuel are unavoidable. Even with the best thermal reactors, it would be almost impossible to use all the uranium. A few fast reactors will easily make up the losses of many thermal reactors, so all the uranium and thorium that can be mined economically can be utilized as fuels. The economic point, as compared with coal, may well be several hundred dollars per pound and the available supplies will certainly last many hundreds of years. In breeders, about 200 tons of uranium would be fissioned to produce the same heat as the burning of 500,000,000 tons of coal. However, many times as much uranium and many thousands of kilograms of plutonium would be required in the reactors to maintain the reaction.

Requirements for materials to be used in fast reactors are relatively simple. The main one, besides cost, is that all materials have medium or high atomic weights. The materials should not slow neutrons down to the intermediate range of energies before they are absorbed in the fissionable Pu^{239} or in the U^{235}. Part of the neutrons in the intermediate range of energies are absorbed in the Pu^{239} without causing the fission process to take place. The practical materials are quickly reduced to:

Fissionable fuel	Pu^{239}
Fertile material	U^{238}
Coolant	Sodium
Structural	Stainless steel
Reflector	Lead, iron

The amount of fuel needed in a fast reactor is many times that required in a thermal reactor, so, normally, the minimum amount of fuel will be used. This fuel should be made into fuel elements designed for the maximum possible heat rate. This in turn will mean that an efficient coolant will be required. Fortunately, liquid metals such as sodium have high heat-transfer film coefficients. At 25 ft./sec. and 750° F. the film coefficient will be about 20,000 B.t.u./(sq.ft.)(hr.)(° F.). When this is used with a high temperature drop between the fuel element and the sodium, high heat tranfer is obtained. Rates as high as 1.0 to 2.0×10^6 B.t.u./(hr.)(sq.ft.) are desired. If the fuel element and its cladding can be made quite thin, 0.10 in. or so, the temperature drop through the fuel plate can be kept low.

The fuel in the fast reactor is combined with just enough fertile material so that the amount of new plutonium formed from the uranium equals that fissioned. In this way the reactivity is maintained relatively constant. The minimum amounts of cladding and coolant are used in the core. This is necessary to obtain the minimum critical mass. In all cases, the critical masses will be high and the investment charge for the fissionable material will be an appreciable charge.

Low volumes of cladding and coolant in the core also favor the maintenance of the high energy spectrum for the neutrons. Much of the loss in energy of the neutrons is due to inelastic scattering. In this process the neutron may be considered to be absorbed and a lower energy neutron re-emitted by a nucleus. As noted previously, elastic impacts with heavy nuclei do not result in appreciable loss in neutron energy.

A thick blanket of natural or depleted uranium is placed outside the core to absorb the neutrons lost from the core. This absorption forms the remainder of the plutonium or excess fuel produced in the breeding process. Depleted uranium has less than 0.711% U^{235} present. Since relatively fewer fissions occur in the blanket than in the core, the uranium may be present in thicker fuel plates or rods. As the reactivity of the blanket increases with time, a portion must be removed occasionally, reprocessed to remove the fission products, and recover the plutonium produced.

Since some neutrons will pass through the blanket without being absorbed, a reflector may be placed outside the blanket to return a portion of the neutrons. Actually, this reflector will be a portion of the shield as it will absorb gamma rays from the core and blanket. The reflector is made of a high atomic-weight material such as iron or lead. It may be combined with water to thermalize a portion of the neutrons. A portion of these thermalized neutrons will diffuse back to the blanket and be productively absorbed and the remainder will be lost. Since lead has a low thermal neutron cross section, it makes a good, but rather costly, reflector.

Since all elements used in stainless steel have high atomic weights, stainless steel is satisfactory for use in fast reactors. Thin cladding and light structural shapes are readily made. In addition, stainless steel can be used at high temperatures, 650° C. or more, with sodium coolant. Zirconium also may be used.

Control of a fast reactor is based on different principles from those on which control of a thermal reactor is based. In a thermal reactor control is maintained by addition or subtraction of small amounts of poison in the form of an element with a high absorption cross section for thermal neutrons. In a fast reactor all materials have low cross section; hence, it is necessary to move a portion of the blanket to increase or decrease the fraction of neutrons which escape from the reactor. Shielding materials for a fast reactor are the same as those used for a thermal reactor. The relative amount of water in the thermal shield is increased as all the neutrons are fast and it is desired to thermalize them as rapidly as possible.

Homogeneous Thermal Reactors

Any system that may hold uranium or thorium in solution or in a suspension is of potential interest for use in homogeneous reactors. A large number of quite feasible systems might be suggested for thermal and fast reactors.

The only moderator that may exist as a fused fluoride, liquid metal, or hydroxide is beryllium. All hydroxides contain adequate amounts of hydrogen for use as the moderator. Most nonaqueous systems suggested to date either have high melting points or low uranium solubility. As uranium is soluble as the nitrate, phosphate, sulfate, and carbonate, several aqueous or acid solutions are feasible. Water (light or heavy) solutions of uranium in one of the above forms may be used in a power reactor.

Water or metal slurries of uranium oxide may be usable, although the questions of stability and corrosion-erosion of such slurries must be answered. Water solutions of uranium sulfate can be utilized with stainless steel and titanium. Zirconium may be used to separate the core containing the fissionable material from the blanket which contains the fertile material.

A homogeneous reactor is simple in design since it consists of a pressurized spherical tank. If the fuel and fertile materials are separated, two concentric tanks are utilized, and the outer tank is pressurized.

Control elements are held in stainless steel or zirconium.

Homogeneous Fast Reactors

Homogeneous fast reactor systems of fused salts or metals could be studied. Bismuth and lead have low melting points and reasonable solubility for uranium. However, corrosion rates are high when such metallic solutions are used in stainless steel.

Summary

The materials of primary interest for use in nuclear reactors designed for civilian power production are presented in Table 5.

Table 5.—Civilian Power Reactor Materials

	Heterogeneous		Homogeneous	
	Thermal	Fast	Thermal	Fast
Fuel	U^{233}	Pu^{239}	U^{235}	Pu^{239}
Fertile	U^{238}	U^{238}	U^{238}	U^{238}
Moderator	H_2O, D_2O, C	none	H_2O, D_2O	none
Coolant	H_2O, D_2O, Na	Na	H_2O, D_2O Solution	Bi, Pb Solution
Cladding and Structural	Al, Zr	s.s.	ss., Zr	s.s.
Control	B, Cd	none	B, Cd	none

U^{233} may be used in all types of thermal reactors as it becomes available.

Power Reactor Design fundamentals

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A résumé of factors to be carefully balanced before 6-mill electric power can be achieved.

Products of the fission reaction are the fission fragments themselves—neutrons, gamma rays, and energy. A nuclear reactor may be designed and constructed to make profitable use of any one or more of these products; the remainder of the products are treated as wastes. The most widely discussed application of the fission reaction today is that in which the energy is utilized for the production of electric power, which is the theme of this paper. In particular, a type of reactor which makes use of some of the "spare" neutrons to make additional fuel will be discussed. The fission fragments and gamma rays will be treated as wastes except insofar as the heat generated by them is recovered.

The technical feasibility of generating electric power from nuclear energy has been well established. Therefore, the concern here is the problem of making this power competitive with that produced from the conventional, or so-called fossil, fuels. An objective set is the production of electric power at 6 mills/kw.-hr. This is defined as the *net* cost of electric energy at the generating station at the high voltage take-off structure.

COST STRUCTURE FOR 6-MILL POWER

As an aid in evaluating, on a dollar basis, the problems of reactor design, a plausible cost structure for 6-mill electric power has been set up. This is shown in Table 1.

For purposes of this paper the reactor chosen is a sodium-cooled, graphite-moderated reactor fueled with low-enrichment uranium. The thermal rating of the reactor is 300 megawatts (mw.); the net electrical output of the plant is 100 mw.

Fuel Investment

In developing the numerical values for the fuel investment charge, the average enrichment of the fuel in the reactor is taken to be 1.05% U^{235}; the cost of natural uranium (0.70% U^{235}), \$20/lb. (*1*). The value of a pound of fuel of 1.05% enrichment is computed first on the assumption that there is no charge for processing the ore through the diffusion plant.

The relationship, developed from considerations of "conservation of mass" (conservation of U^{235} and U^{238}), is

$$F \times \frac{N_p - N_w}{N_f - N_w} = P' \qquad (1)$$

where

F = feed cost, \$/lb.
P' = product cost, \$/lb. (neglecting cost of diffusion process)
N_f = feed enrichment, %
N_p = product enrichment, %
N_w = waste concentration, %

Equation (1) may also be written

$$F \times \frac{N_p}{N_f} \times \frac{1 - \frac{N_w}{N_p}}{1 - \frac{N_w}{N_f}} = P' \qquad (2)$$

in which N_p/N_f may be identified as the enrichment factor while the other fraction may be called the "material inefficiency" of the diffusion process. Evaluating the equation for a feed enrichment of 0.70%, a product enrichment of 1.05% and a waste concentration of 0.35%, the product cost is \$40/lb. The numbers used are close to typical values quoted in the unclassified literature; the exact values chosen are the feed enrichment multiplied by simple fractions—3/2 and 1/2.

The procedure now is to calculate the diffusion-plant processing cost, per pound of natural uranium feed, which is added to the feed cost in Equation (1) to give the value of the product including the cost of the diffusion process. Equation (1) becomes

$$(F + D) \times \frac{N_p - N_w}{N_f - N_w} = P \qquad (3)$$

where

D = diffusion-plant processing cost, \$/lb. (of feed material)
P = product cost, \$/lb. (including cost of diffusion process)

D is determined by evaluating Equation (3) for $N_p = 100\%$ and setting P equal to \$9,072, the cost of 1 lb. of U^{235} at \$20/g. (*2*). This gives for D a value of \$11.75, the cost of processing 1 lb. of uranium ore. For lack of other data the conservative assumption is made that the processing cost per pound of feed is constant regardless of the enrichment of the product.

The cost of 1.05% enrichment fuel now becomes \$63.50/lb. This figure is now used to compute the fuel investment charge. It is assumed that (1) there is a negligible fuel inventory in the power plant outside the reactor and, (2) the investment charge on fuel being reprocessed is assumed by the processor and is included in the diffusion-plant processing charge. Taking a specific power of 13 megawatts /ton in the fuel and a 10% annual charge on the fuel inventory (which is nondepreciating), for an 80% plant factor and a 33⅓% net thermal efficiency, the fuel investment charge in mills/kw.-hr. (electric) is 0.42.

Table 1.—Assumed Cost Structure for 6-Mill Power

Investment charges	\$/kw.	Mills/kw.-hr.
Fuel	\$ 20	0.42
Moderator	3	0.06
Reflector and shield	7	0.16
Reactor structure and cooling system, buildings & site	90	1.90
Reactor auxiliaries, buildings & site	10	0.21
Power plant, buildings & site	90	1.90
	\$220	4.65
Operating costs		
Fuel		1.10
Operation and maintenance		0.25
		6.00

Moderator

The specific power in the moderator is assumed to be 3 mw./ton or approximately ¼ of that in the fuel. The cost

of moderator graphite is taken as $1.50/lb. installed. Then for a 15% annual charge on investment, an 80% plant factor, and a 33⅓% net thermal efficiency the moderator investment charge in mills/kw.-hr. (electric) is 0.06.

The specific power in the moderator is simply the thermal output of the reactor in megawatts divided by the weight of moderator in tons (not including the reflector graphite). Neglecting fuel and coolant, 3 mw./ton gives for a 300-mw. reactor a core weight of 100 tons and a volume of approximately 2,000 cu.ft. This is equivalent to a right circular cylinder with diameter and height equal to 13 ft., 8 in.

Reflector and Shield

For calculating this item a configuration is assumed with radial (and top and bottom) thicknesses of material as follows: 2 ft., 6 in. of graphite (reflector), 6 in. of void, 10 in. of iron (thermal shield), 2 in. of void, and 6 ft. of concrete (biological shield). The material costs are taken to be 75 cents/lb., $70/ton, and $125/yd., respectively; the installed cost is twice the material cost. For the subject 300-mw. reactor the total reflector and shield cost is approximately $750,000. Using a 15% annual charge on investment, an 80% plant factor, and a 33⅓% net thermal efficiency, the reflector and shield become an investment charge in mills/kw.-hr. (electric) of 0.16.

The moderator, reflector, and shield form a cylinder approximately 34 ft. in diam. and 34 ft. high.

Reactor Structure and Cooling System

By definition here this system includes the cooling system within the reactor and the entire heat-transfer system up to the superheater outlet of the steam generator. This item covers such elements as reactor core tank, reactor coolant channels, inlet and discharge manifolds, piping, pumps, and heat exchangers. For lack of specific data the cost of the cooling system is assumed to be equal to the cost of the power plant (described below), that is, $30/kw. capacity (thermal) or $90/kw. capacity (net electric). The implications of this assumption regarding the cost of the cooling system are discussed below. With a plant factor of 80%, a net thermal efficiency of 33⅓%, and an annual charge on capital of 15%, the cooling system investment charge in mills/kw.-hr. (electric) becomes 1.90.

Auxiliaries, Buildings, and Site (for reactor, not cooling system)

This item is established as the difference between the assumed selling cost of 6 mills/kw.-hr. and the sum of all other items. It is, in mills/kw.-hr. (electric), 0.21.

Power Plant

This item covers the power-conversion equipment including buildings and structures and a proportionate share of site and improvements. The cost is assumed to be $90/kw. capacity (electric). With the 80% plant factor, 33⅓% thermal efficiency, and 15% annual charge on capital used above, the investment charge in mills/kw.-hr. (electric) becomes 1.90.

"Burned" Fuel Cost

In discussing the fuel-investment charge above, it was assumed that the average enrichment of the fuel in the reactor during operation was 1.05% (1½ × natural enrichment). For evaluating the "burned" cost it is assumed that a fuel supplier delivers to the plant operators fresh or "clean" fuel, that is, not radioactive, with an enrichment of 1.225% (1¾ × natural enrichment). It is assumed further that the irradiated fuel is removed from the reactor and returned to the fuel fabricator when the average enrichment has been reduced to 0.875% (1¼ × natural enrichment). The cost of the fresh fuel may be computed through the application of Equation (3). The value of the irradiated fuel is also computed from Equation (3) on the assumption that fuel-decontamination charges and fuel-fabrication charges are relatively small. This optimistic statement is made since no specific data are available. The figures are

Cost for new fuel, 1.225% U^{235}	$79.38/lb.
Credit for irradiated fuel, 0.875% U^{235} (credit for U^{235} content only)	47.63/lb.
Cost of burning fuel	$31.75/lb.

It was stated earlier that the reactor system chosen is one which makes use of some of the spare neutrons from the fission reaction to make additional fuel. If it is assumed that the conversion ratio is 0.7, the irradiated fuel will contain one gram of plutonium per pound of uranium. It appears reasonable to assume that plutonium is equal in value to pure U^{235} as a fuel, that is, $20/g. (The value for U^{235} and plutonium should possibly be weighed by a factor related to the ratio of neutrons produced per thermal neutron absorbed in the two fuels, 2.11 to 1.95; however, for simplicity no such factor is introduced here.) Allowing this credit (no allowance for chemical cost for recovery of the plutonium) a new "burned" fuel cost is $31.75 − $20 = $11.75/lb. The heating value of this fuel (1.225% fuel burned to 0.875% with a conversion ratio of 0.7) is approximately 2,650 mw. days/ton. The fuel cost is then 0.37 mill/kw.-hr. (thermal). With a net thermal efficiency of 33⅓%, the cost in mills/kw.-hr. (electric) is 1.10.

Operating and Maintenance Costs

The lack of experience with atomic plants makes it necessary to carry over figures for this item from conventional plants. A good figure (on the low side) in mills/kw.-hr. (electric) is 0.25.

REACTOR MATERIALS

From the summary just presented it is evident that the largest items subject to control by the reactor designer are the fuel items and the cooling system. It is also important, of course, for the reactor designer to watch the cost of auxiliaries and buildings to be sure that this item does not get "out of hand."

Fuel

Fuel appears in the cost structure twice, first, as an investment item and, second, as an operating cost. The fuel investment charge is a function of the plant factor, thermal efficiency, mode of financing, cost of fuel, and the specific power in the fuel. The cost of fuel, in turn, is a function of the ore cost, enrichment, processing cost, and fuel-element fabrication cost. The specific power depends upon the fuel geometry and the operating temperatures in the fuel and coolant. The reactor designer controls directly the enrichment, specific power, and thermal efficiency, and, indirectly, by good design of the plant and auxiliaries, the plant factor.

The relationship between fuel cost and enrichment may be shown graphically by plotting the factor $N_p - N_w/N_f - N_w$ as a function of N_p with N_w as a parameter. This is shown in Figure 1. The enrichment required is, of course, dependent on the core geometry and the materials of construction.

The fuel operating cost or "burned"-fuel cost is a function of enrichment and

Table 2.—Neutron Economy of Sodium-Graphite Reactor Fueled with Low-Enrichment Uranium

Neutrons/fission	2.5
Fast leakage	0.1
Resonance absorption in U^{235}	0.4
Leakage and absorption above thermal energy	0.5
Neutrons/fission becoming thermal	2.0
Fission capture in U^{235}	1.0
Thermal capture in U^{238}	0.3
Non-fission capture in U^{235}, thermal leakage and parasitic absorption	0.7
Thermal leakage and absorption	2.0
	0.

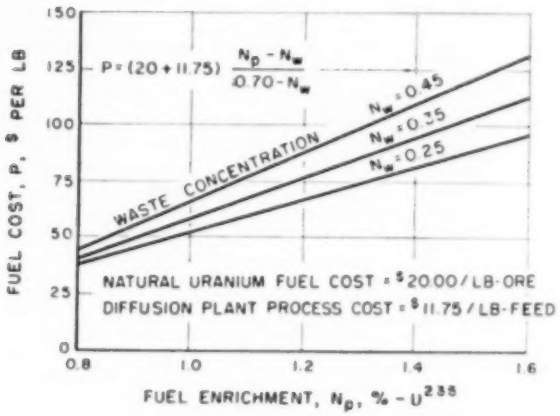

Fig. 1. (Left) Cost of low-enrichment uranium fuel.

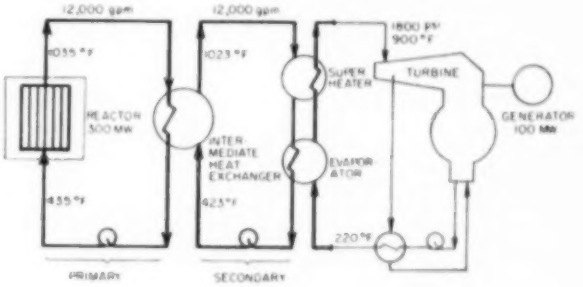

Fig. 2. (Above) Cooling system, sodium-graphite reactor.

conversion ratio, and, of course, ore cost and diffusion-plant processing cost, which is understood to include the fuel-element fabrication expense and, for recycled fuel, the decontamination charge. For assumed values of ore cost and processing cost, the effect of varying enrichment, burn-up, and conversion ratio may be shown through the application of Equation (3). In these calculations figures for plutonium production must also be introduced and from these dollar credits should be derived with the value assumed above of $20/g.

Moderators

The investment charge for the moderator material is apparently a small item in the case of graphite. The incentive to reduce the quantity of moderator (by increasing the specific power) comes from a desire to reduce the core size and, thereby, lower the investment charge for the reflector and shield. The incentive to increase its purity (thereby lowering the parasitic absorption of neutrons) comes from the desire to lower the enrichment and raise the conversion ratio, thereby reducing the investment charge for the fuel as well as lowering the "burned" fuel cost.

The premium which the designer will pay for removal of impurities from graphite may be related to the parasitic absorption of neutrons by the impurities and the equivalent loss in plutonium production. One gram-mole of neutrons captured by U^{238} is assumed to convert 1 g.-mole (238 g.) of the U^{238} (assumed valueless) to 1 g.-mole of plutonium (239 g.) with a value of $239 \times \$20 = \$4{,}780$. The effects of changes in buckling, fuel enrichment, etc., all tend to increase the premium but are neglected in this approximation. It is now necessary to determine what fraction of neutrons freed by the removal of thermal poison from the moderator would be captured by the U^{238}. Considering the neutron "economy" of the reactor under discussion is an approach to the problem. A reasonable breakdown is shown in Table 2.

A reduction in the impurities in the graphite amounts to a small change in parasitic absorption. It is apparent that with the removal of poison there is only a certain probability that the neutron not now captured by the poison will be captured by the U^{238} to form plutonium. This probability is, to a first approximation, 0.3/2.0 or 15%. In this reactor then 1 g.-mole of thermal neutrons is worth 15% of $4,780 or $717.

In the case of boron it can be shown that substantially all the B^{10} will be burned out in the first few years of operation (90% in two years with an average flux in the graphite of 5×10^{13}). One part per million of boron in graphite is equivalent to approximately 8×10^{-5} g. of B^{10}/lb. or 8×10^{-6} g.-moles of B^{10}/lb. One gram-mole of B^{10} will consume 1 g.-mole of neutrons; hence 8×10^{-6} g./moles of boron will consume neutrons worth $717 $\times 8 \times 10^{-6} = 0.6$ cent. That is to say, the designer will pay a premium of 0.6 cent/lb. for graphite for a reduction of 1 p.p.m. of boron.

Structural Materials

In the selection of structural materials for the reactor core, consideration is given to the cross section for neutron capture, to the strength and to the compatibility with the coolant at elevated temperature. The neutron cross section influences the fuel items through enrichment and conversion ratio. High strength and low corrosion at elevated temperature will permit operation of the coolant at high temperature, thereby permitting a high thermal conversion efficiency for the power cycle. This then will affect all the items which make up the cost of power with the exception of the operation and maintenance expense. (By the definition used here this expense is related directly to electric power production.)

The premium which the designer will pay for structural materials with a low-neutron absorption cross section on the basis of the *decrease in parasitic absorption of neutrons only* (the premium arising from the lower enrichment of the fuel is discussed below) may be developed from the supposed plutonium loss as in the case of impurities in the moderator. For iron and zirconium it may be shown that there is negligible burn-out effect at the assumed flux of 5×10^{13} over an assumed life of the reactor of twenty years. The loss in plutonium production per year, therefore, is substantially constant. This loss in plutonium production may be capitalized to show the value of the low cross section of the material to the designer.

In one year, 1 lb. of iron will absorb approximately 0.03 g.-mole of neutrons worth approximately $21.50. A pound of zirconium, on the other hand, will absorb in one year only 0.0015 g. of neutrons, to which one can assign a value of $1.08. Capitalizing the difference of $20.42 at an annual capital charge of 15% gives a figure of $135/lb. as being the premium which the designer would be willing to pay for zirconium over steel where a pound of zirconium will replace a pound of steel. It must be recognized, of course, that at the temperatures mentioned for this reactor, replacement of zirconium for iron on a pound-for-pound basis may not be possible. The weight of zirconium required may be somewhat greater than the weight of steel it replaces. These figures are, of course, the premium per pound fabricated and in place.

The premium which the designer will pay for structural materials with a low-neutron cross section on the basis of a resulting *decrease in the enrichment of the fuel* may be developed, to a rough first approximation, from a consideration of the fractional increase in enrichment required to compensate for small additions of an alloying element to the fuel in a sodium-graphite reactor. For an element with a neutron cross

Table 3.—Cooling System Cost Breakdown

Component	First Cost $/thermal kw.	First Cost for a 300 mw. (thermal) reactor plant
Reactor container	$4.00	$1,200,000
Piping, primary coolant system	2.00	600,000
Pumps, primary system	2.00	600,000
Sodium-to-sodium heat exchanger	8.00	2,400,000
Piping, secondary coolant system	2.00	600,000
Pumps, secondary system	2.00	600,000
Steam generator	6.00	1,800,000
Buildings and site (including shielding external to the reactor)	2.00	600,000
Auxiliaries (fill and drain facilities, cold traps, etc.)	2.00	600,000
	$30.00	$9,000,000

section of 2.4 barns, such as iron, one atom per cent addition to the fuel results in a fractional increase in enrichment of 0.8%. In the reactor under discussion, in which the average fuel enrichment is 1.05%, an 0.8% increased enrichment corresponds to an increase in fuel cost of 69 cents/lb. of uranium; one atom per cent iron in uranium is equivalent to 0.00235 lb. of iron/lb. of uranium; 0.00235 lb. of iron, then, increases the total fuel cost by 69 cents, and 1 lb. of iron in the reactor core will increase the cost of fuel by $290.

It is now interesting to calculate the same quantity for zirconium. If it is assumed that the effect on enrichment is proportional to the cross section (0.18 Zr/2.4 Fe), one atom per cent zirconium in uranium (0.00382 lb. of zirconium/lb. of uranium) will increase the cost of fuel by $0.18/2.4 \times 69$ cents = 5.2 cents/lb. One pound of zirconium in the reactor core then corresponds to an increase in the cost of fuel in the reactor of $13.20. Neglecting the different annual investment charges on fuel and structural material, which were assumed earlier, the difference $290 − $13.60 = $276.40, is the premium per pound which the designer will pay for zirconium over iron assuming substitution on a pound-for-pound basis. This is the premium resulting from the lowering of the enrichment of the fuel; this premium may be considered as adding to that developed above on the basis of an increase in plutonium production.

Reflector and Shield Materials

The contribution from this item is not large; however, a substantial reduction should be obtainable through refinement of design. By placing the reactor underground, substantial savings may be effected through relaxation on tolerances for stray radiation.

Coolants

The capital cost of sodium is small and is, therefore, not included as a separate item. Considerations in the selection of the coolant are the neutron-capture cross section (which, as noted above, may influence the fuel items through enrichment and conversion ratio) and the physical properties such as boiling point, specific heat, viscosity, and thermal conductivity, which will determine the quantity of the coolant, pumping power, system pressure, and thermal efficiency.

REACTOR STRUCTURE AND COOLING SYSTEM

The cooling system is a large item and one for which little information is available where the coolant is sodium. For purposes of this paper it is assumed that there are two coolant loops, a primary loop including the reactor in which the sodium becomes radioactive and a secondary or intermediate loop containing sodium which is not radioactive. The arrangement is shown in the diagram in Figure 2. A plausible, but rather arbitrary, breakdown for the $30/thermal kw. permissible investment in this cooling system (from Table 1) is given in Table 3.

Pumps

To determine the number and size of pumps it is assumed that the temperature rise in the coolant in passing through the reactor is 600° F. and that the capacity of each pump is 1200 gal./min. (*3*). The number of pumps for a 300-mw. plant is then 10, and the allowable cost per unit is $60,000 using the schedule in Table 3. This figure may be assumed to include the driving motor, control equipment, and a proportionate share of the electric plant.

Heat Exchangers

Steam conditions at the turbine throttle are taken as 1,800 lb./sq.in. 900° F. T.T. (net thermal efficiency 33⅓%). To determine the number of square feet of heat-exchange area it is assumed that the log mean temperature differences are 12° F. in the sodium-to-sodium exchanger, 100° F. in the evaporator, and 200° F. in the superheater: also that the over-all heat-transfer coefficients, or U's [B.t.u./(sq.ft.)(hr.)(° F.)], for these exchangers are 1,000, 300, and 150 respectively (*4*). In the case of the evaporator and superheater, it is presumed that double-walled tube construction will be required in the interest of safety. It is assumed further that a third fluid, mercury, is used as a monitoring medium in the annular space between the inner and outer tubes. The sodium temperatures at the reactor are 435° F. in, and 1,050° F. out. For the 300-mw. reactor under discussion, 83,000 sq.ft. of heat transfer area are required for the sodium-to-sodium intermediate exchanger. Using the gross figure of $2,400,000 in Table 3 gives as the allowable cost of this exchanger per square foot installed, $29.00.

In the steam cycle the feed water temperature is taken to be 220° F. The fraction of the reactor heat then, which is transferred through the superheater, is approximately 22% of the total heat. The areas of the superheater and evaporator-economizer calculate to be 7,000 sq.ft. and 26,000 sq.ft., respectively. If construction costs per square foot are taken to be the same (these are both high pressure units with double-walled tubes), the allowable cost per square foot is $55.00. This is installed cost. It may be assumed that only the inner tubes in the evaporator are stainless steel (outer tubes and shell, alloy steel) and that the shell and outer tubes are stainless steel in the superheater.

CONCLUSION

It appears that attainment of 6-mill electric power from atomic energy is a difficult, but far from impossible, task. The problems are engineering ones not unlike those encountered in the design and construction of more conventional equipment. They are the problems of extracting heat at high rates and at high temperatures from inexpensive fuels burned in low-cost equipment which is simply operated and easily maintained. And most important of all is the requirement that the system have a high over-all availability.

ACKNOWLEDGMENT

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Gamma-Activation of

Syntheses —polymerization of ethylene

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The promotion of industrially significant chemical reactions using fission waste products as radiation sources offers many intriguing possibilities. To discover and develop useful applications for the fission products that are now regarded as costly wastes, the Atomic Energy Commission instituted a series of investigations at laboratories and universities. The use of radiation from such fission products to catalyze or promote chemical reactions is the subject of this paper.

Ethylene, among many other substances studied, has been polymerized by gamma radiation to form solid products. This was studied by Bretton, et al. (2) at 1 atm. and at temperatures ranging from room conditions to 372° F.

Since the manufacture of polyethylene is becoming increasingly important, it was decided to investigate the possibilities of promotion of the reaction through the use of such gamma radiation.

The gross fission products are powerful emitters of gamma and beta radiation, both of which, it has long been known, can cause chemical reactions. Beta radiation has a very low penetrating power; therefore, applying it to promote chemical reaction requires almost direct contact between the reacting chemicals and the source of radiation. Since the fission products might contaminate any chemical products in direct contact, most of this study was devoted to promoting chemical reactions by highly penetrating gamma radiation emanating from a source that can be kept isolated from the reacting chemicals.

When this work was started fission product sources of gamma radiation had not been made available by the Atomic Energy Commission because of difficulties in concentrating and packaging the fission products. However, several government laboratories were producing in nuclear piles artificial cobalt-60, which emits a gamma radiation comparable, though not identical, with the spectrum of gamma emissions from gross fission products. Two cobalt-60 sources were used to supply the radiation for these studies. One of these sources was nominally rated at one kilocurie and the other at ten kilocuries (*3, 14*).

Many compounds and mixtures of different compounds were irradiated with the cobalt-60 sources and a number of chemical reactions were detected, among them the polymerization of ethylene gas both pure and mixed with other compounds.

Previous Work

Ethylene was polymerized at 77° F. and about 1 atm. by Lind, Bardwell, and Perry (*13*) using alpha radiation from radon to initiate the reaction. The products were liquids, reported to be olefins of higher molecular weight, and gases, reported to be hydrogen and methane.

Ethylene was observed to polymerize when irradiated with ultraviolet light. LeRoy and Steacie (*10*) noted that the metal sensitizers—cadmium, zinc, and mercury—accelerated the polymerization of ethylene irradiated with ultraviolet light and simultaneously caused some dehydrogenation to acetylene. In this work temperatures ranged from 77° to 572° F. and pressures from 15 to 400 mm. Hg abs. Danby and Hinshelwood (*4*) investigated the polymerization of ethylene by ultraviolet light at 572° F. and pressures to 400 mm. Hg abs., as sensitized by acetone, by diethyl ketone, and by acetaldehyde. Taylor and Emeleus (*19*) found that the polymerization of ethylene was photosensitized by ammonia at 68° to 212° F. and 5 to 15 cm. Hg though no solid polymer was produced. These reactions were studied chiefly in the gas phase.

As stated previously ethylene was also polymerized by gamma radiation. The products were solids, usually yellowish or brown in color; other properties were not reported.

Apparatus

A special reactor bomb (Figure 1) designed to work at 2,000 lb./sq.in. and 650° F. was constructed and used for the polymerization of ethylene by means of gamma irradiation. It was necessary for the reactor to be inserted into an access hole 1½ in. in diameter in the kilocurie cobalt-60 source (*14*). The thickness of the walls of the vessel was kept to a minimum in order to make maximum working space available within the bomb and to allow a maximum amount of gamma radiation to pass through to the contents. AISI 304 stainless steel was chosen as the material of construction for the head, body, and flanges of the bomb. The parts were welded together with AISI 347 rod, except for the body flange, which was screwed on. A tongue-and-groove joint was used between the body and the head. The tongue was machined on the body, the walls of which were too thin to receive the groove. In order to fit inside the kilocurie source the head-flanges were of slightly smaller diameter and thickness than are normally recommended. In spite of the small size the head of the bomb accommodated two electrical power leads, four thermocouple leads, an entrance line, an exit line, a pressure gauge, and a rupture disc. There was barely room for two ¼-in. tubing lines inside the gasket circle of the head, and consequently most of the connections were made through the side of the bar which was used for the head. The same set of holes was used to admit process materials and electrical leads, and the pressure gauge and rupture disc were placed on the external tubing lines. The bomb was hydrostatically tested at

2,800 lb./sq.in. and hammer tested at 2,000 lb./sq.in., and all welds were radiographed before the vessel was placed in service.

Experimental Procedure

In this work ethylene was irradiated while at room temperature at pressures of 250 to 1,600 lb./sq.in. In some tests ethylene was reacted alone and in some ethylene was mixed with other reactants. Before a run the reaction bomb was evacuated to a pressure of less than 1 mm. Hg, and then ethylene was added from a supply cylinder. The bomb was next placed in either the 1 kilocurie source or the 10 kilocurie source until the proper dose had been accumulated. After irradiation the bomb was removed from the source, the unreacted ethylene was vented and analyzed by an Orsat apparatus, and the accumulated polymer was removed mechanically and weighed. The mass of ethylene charged to the bomb was determined from the measured temperature, pressure, and volume by means of the thermodynamic properties given by York and White (*20*). The conditions prevailing during reaction were noted and average values were assumed to have prevailed throughout the course of the reaction.

Results of Irradiating Ethylene

A white solid polyethylene resulted from the irradiation of ethylene with cobalt-60 gamma rays. A quantitative measure of the reaction was determined by calculating the radiation yield in terms of the G value, that is, the number of molecules of ethylene undergoing polymerization/100 electron volts of energy absorbed from the radiation. The roentgen equivalent physical, or rep, was adopted as the unit of measure of the absorption of gamma radiation by ethylene. The rep was taken to correspond to the absorption of 93 ergs/g. of absorber as is customary in this field. The dose rate in rep per hour in the absorber was determined by a combination of methods. Chemical dosimetry was conducted by Harmer (*1*) using the method of Weiss (*21*), and the results were correlated and extended by the methods of Lewis, Nehemias, Harmer, and Martin (*11*). The dose rates so determined were applied to the calculations of the radiation yields.

In place of G a quantity A was generally calculated in this work. A was defined as the gram moles reacted per metric ton of ethylene charged per megarep of radiation. By a comparison of units the following relation was established:

$$A\left(\frac{\text{gram moles reacted}}{\text{metric ton} \times \text{megarep}}\right) = \frac{G}{1.04}\left(\frac{\text{molecules reacted}}{100 \text{ electron volts}}\right)$$

Consequently, A was almost equal numerically to G, and the dimensions of the two quantities were equivalent. With some simplification the following relation was developed:

$$A\left(\frac{\text{gram moles reacted}}{\text{metric ton} \times \text{megarep}}\right) = \frac{\text{weight fraction ethylene reacted} \times 10^6}{\text{molecular weight of ethylene} \times \text{dose, megarep}}$$

The simplified relation was used in calculating A values in the following work. These A values were plotted versus the radiation dose in Figure 2.

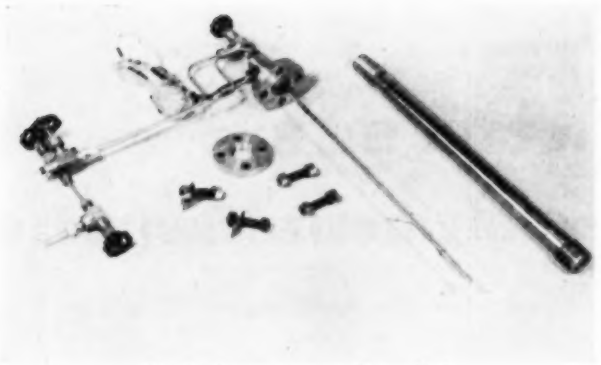

Fig. 1. Pressure reactor disassembled.

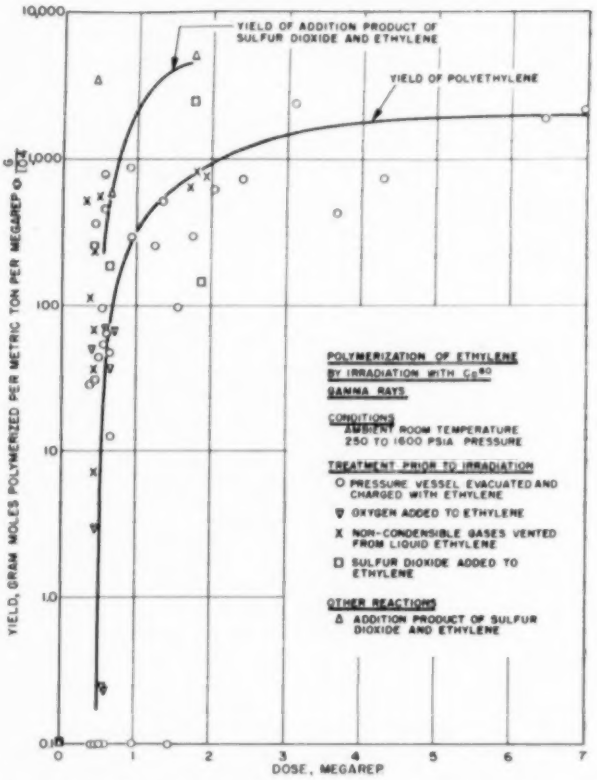

Fig. 2. Radiation yield as function of dose of radiation in polymerization of ethylene.

The yield of polymer was found to be quite small until the system had received a dose of about ¼ megarep. The yield then increased rapidly to a value of about 2,500 g. moles reacted/(metric ton)(megarep) at about 3 megarep and remained nearly constant up to doses of 7 megarep, the highest dose studied (see Figure 2). It should be noted that 1 g. mole reacted/(metric ton)(megarep) is equivalent to 0.97 molecule reacted/100 electron volts. About ⅓ of the monomer was polymerized in three days in the center of the 10 kilocurie source.

Table 1 — Experimental Data

Order No.	Page No.	Starting Date	Psig Initial	Psig Final	Avg. Psia	Avg. Temp., °F	Grams Polymer	Hours Irrad.	Grams Polymer per Hour	A = G-Moles Reacted / (Metric Ton)(Megarep)	Averaged over Reactor: Dose Rate Kilorep/Hr	Averaged over Reactor: Total Dose Megarep	Other Reactants	Source	Position of Reactor	Mfr.	Cylinder No.	Remarks
2	132113	19 Dec 52	830	785	802	69	1.64	69.7	0.024	608.	29.	2.02	1 Ml acetone	1 kc	--	Matheson	FF 757	--
3	132118	12 Jan 53	800	795	802	70	0.656	61.	0.011	291.	18.9	1.76	--	1 kc	--	"	"	--
4	132147	3 Mar 53	1430	1330	1395	200	0.292	17.2	0.017	489.	29.5	0.507	--	10 kc	8" NR 9" up	"	"	--
5	132149-II	7 Mar 53	820 / 435	700 / 424	775 / 445	50	0.004	0.9 / 15.	0.0003	12.7	40.	0.666	--	10 kc	8" NR 9" up	"	"	--
1	132159	26 Nov 52	790	780	800	68	0.394	42.	0.009	258	29.5	1.24	1 Ml acetone	1 kc	--	"	"	--
6	132250	10 Mar 53	810	715	777	50	0.167	16.2	0.010	94.5	96.	1.55	--	10 kc	C on C Base at Base	"	"	--
7	132252	11 Mar 53	1430	1330	1395	200	1.04	16.1	0.06	513.	80.5	1.33	--	10 kc	Do.	"	"	--
8	132253	12 Mar 53	698	692	710	45	1.48	87.7	0.017	425.	42.0	3.69	--	10 kc	8" NR 9" up	"	"	--
9	132254	17 Mar 53	635	655	660	45	--	23.3	--	--	42.0	0.979	650 psi N_2 and 15 psi air vent, chg. C_2H_4	10 kc	8" NR 9" up	"	"	--
10	132255	18 Mar 53	800	710	770	45	0.088	21.5	0.004	865.	42.0	0.904	--	10 kc	8" NR 9" up	"	"	--
11	132256	19 Mar 53	840	760	815	420	0.581	15.3	0.045	1800.	29.5	0.448	--	10 kc	8" NR 9" up	"	"	--
12	132258	23 Mar 53	810	70	455	45	0.010	39.	0.0003	12.5	41.9	1.63	10 Ml acetone	10 kc	--	"	"	Leak
13	132259	26 Mar 53	798	185	489	61	--	15.5	--	--	95.5	1.46	--	10 kc	C on C Base at Base	"	"	--
14	132263-I	4 May 53	1600	1425	1508	72	--	21.9	--	--	27.7	0.608	--	1 kc	--	"	"	--
15	132263-II	5 May 53	620	595	621	72	0.002	23.	0.001	45.8	27.7	0.638	--	1 kc	--	"	"	--
16	132264	7 May 53	615	600	622	69	<0.0001	20.7	<0.000005	<0.25	27.6	0.572	100 Ml O_2	1 kc	--	"	"	--
17	132265	8 May 53	620	608	631	67	<0.0001	21.4	<0.000005	<0.24	27.6	0.591	25 Ml O_2	1 kc	--	"	"	--
18	132266	9 May 53	594	577	601	72	0.074	25.6	0.0013	67.5	27.5	0.703	5.0 Ml O_2	1 kc	--	"	"	--
19	132267	10 May 53	600	575	603	73	~0.001	17.0	~0.00005	~ 3.1	27.5	0.468	2.0 Ml O_2	1 kc	--	"	"	--
20	132268	11 May 53	617	597	622	70	0.017	22.5	0.0008	36.6	27.5	0.615	10.0 Ml O_2	1 kc	--	"	"	--
21	132269	12 May 53	605	590	612	71	0.030	21.1	0.0014	71.	27.5	0.581	10.0 Ml O_2	1 kc	--	"	"	--
22	132270	13 May 53	637	629	638	66	0.016	14.8	0.0011	50.	27.5	0.407	5.0 Ml O_2	1 kc	--	"	"	--
23	132271	4 Jun 53	550	525	559	70	0.051	16.8	0.003	94.	31.5	0.526	--	10 kc	8" DR 15-7/8" up	"	"	--
24	132276	7 Jul 53	490	490	505	70	0.021	22.1	0.001	63.	27.0	0.597	25 mm air 1 Ml acetone	1 kc	--	"	"	--
25	132277	8 Jul 53	460	460	475	78	--	20.1	--	0.0	27.0	0.543	95 Ml air 1 Ml water	1 kc	--	"	"	--
26	132278	9 Jul 53	460	455	475	73	0.011	18.3	0.0006	43.1	27.0	0.494	215 mm CO_2	1 kc	--	"	"	--
27	132279	10 Jul 53	445	440	458	~75	0.136	59.8	0.002	147.	27.0	1.58	55 mm SO_2	1 kc	--	"	"	--
28	132280	13 Jul 53	426	395	425	87	Lost, several grams tar	16.5	--	--	27.0	0.446	4.596 gm $AlCl_3$	1 kc	--	"	"	--
29	132281	14 Jul 53	430	420	440	81	0.013	20.0	0.001	52.2	27.0	0.540	--	1 kc	--	"	"	A_{SO_2} = 575
30	132282	15 Jul 53	430	410	430	79	0.657	23.2	0.028	184.	27.0	0.627	1 atm SO_2	1 kc	--	"	"	A_{SO_2} = 3380
31	132284	16 Jul 53	420	385	417	83	2.692	16.1	0.167	941.	27.0	0.435	66 psia SO_2	1 kc	--	"	"	A_{SO_2} = 4800
32	132285	17 Jul 53	393	70	246	83	30.9	64.0	0.483	2450.	27.0	1.73	25.98 gm SO_2	1 kc	--	"	"	--
33	132287	20 Jul 53	400	390	410	--	--	--	--	--	0	0	27.9 gm SO_2	--	--	"	"	--
34	132293	3 Aug 53	810	790	815	80	0.206	17.0	0.012	597.	26.8	0.456	--	1 kc	--	Ohio Chem.	320687	--
35	132294	4 Aug 53	970	910	935	76	0.472	21.8	0.022	445.	26.8	0.584	--	1 kc	--	"	"	--
36	132295	5 Aug 53	615	610	628	76	0.010	16.0	0.0006	30.	26.8	0.428	Alk. syringelin	1 kc	--	Matheson	FF 757	--
37	132297	6 Aug 53	975	950	968	77	4.40	71.5	0.0625	750.	26.8	1.91	--	1 kc	--	"	"	Powdery, soft lumps, white
38	132350	10 Aug 53	520	500	535	75	0.005	15.7	0.0005	31.6	26.8	0.421	--	1 kc	--	"	"	--
39	132351	11 Aug 53	985	965	990	80	0.084	16.3	0.005	67.	26.8	0.437	--	1 kc	--	"	"	--
40	132353	12 Aug 53	945	930	950	73	0.085	14.6	0.006	112.	26.8	0.392	--	1 kc	--	"	"	--
41	132354	13 Aug 53	860	840	865	80	0.150	16.3	0.009	174.	26.8	0.437	--	1 kc	--	"	"	--
42	132355	14 Aug 53	870	815	847	74	1.70	65.6	0.0258	658.	26.8	1.70	--	1 kc	--	"	"	--
43	132356	17 Aug 53	955	900	932	70	0.309	11.8	0.0262	509.	26.7	0.315	--	1 kc	--	Ohio Chem.	320687	--
44	132357	18 Aug 53	875	870	888	72	0.428	18.5	0.0231	551.	26.7	0.494	--	1 kc	--	"	"	--
45	132359	20 Aug 53	1015	970	1002	71	~0.005	17.4	≈0.0003	7.5	26.7	0.465	--	1 kc	--	Matheson	1772	--
46	132360	21 Aug 53	920	845	907	74	2.6	66.8	0.040	800.	26.7	1.78	--	1 kc	--	"	"	--
47	132361	24 Aug 53	825	785	820	79	--	15.7	--	0.0	26.5	0.416	--	1 kc	--	"	"	--
48	132362	25 Aug 53	975	945	975	79	0.589	14.0	0.0381	28.0	26.5	0.372	--	1 kc	--	"	"	--
49	132363	26 Aug 53	1200	1000	1115	90	21.5	116.5	0.185	2980.	26.5	3.09	--	1 kc	--	Carlisle and Carton	JK 570551	In small to medium lumps, slightly off white, moderately coherent
50	132366	1 Sept 53	1010	904	950	77	4.9	90.5	0.0541	730.	26.5	2.40	--	1 kc	--	Matheson	1772	Powdery, in small, soft lumps, white
51	132369	9 Sept 53	1005	905	950	73	--	17.0	--	0.0	26.5	0.451	--	1 kc	--	"	"	--
52	132370	10 Sept 53	1000	970	1000	70	1.5	21.3	0.0705	790.	26.5	0.565	--	1 kc	--	Carlisle and Carton	JK 570551	--
53	132372	11 Sept 53	515	475	510	80	0.16	54.9	0.00464	298.	26.5	0.912	Acetaldehyde	1 kc	--	Matheson	1772	--
54	132373	14 Sept 53	1500	960	1245	~70	51.3	262.7	0.195	2200.	26.5	6.97	--	1 kc	--	"	"	Had to be cut out of bomb. Some fines, all coherent, white
55	132375	25 Sept 53	1570	1080	1315	~60	45.6	71.8	0.607	1915. avg	89.6	6.43	--	10 kc	On C --	"	"	Had to be cut out of bomb. Some fines, all coherent, white
56	132376	30 Sept 53	1750	1110	1450	79	12.5	17.0 25.7 28.8	0.18 avg	745. avg	29.5 89.5 98.0	0.50 2.12 1.67	--	1 kc 10 kc 10 kc	On C 6-5/8 out	U.S. Ind. Chem.	I 1065	White, soft powder, very small lumps

Table 2—Analyses of Ethylene from Storage Cylinders and from Reactor

Material No.	Dose	G	Experiment No.	Mfr.	% CO_2	% O_2	% CO	% N_2	% Combustible as marked		No. of Determinations
1				Math FF737	0.06	0.02	0.02	0.15	0.1	propane?	duplicate
2				Math 5772	0.06	0.02±	0.00	0.07	0.29	propane	duplicate
3				OC G28087	0.10±	0.02±	0.00+	0.47 total		ethane?	single sample
4				C and C JK370331	0.37	0.02	0.05	1.7	0.8	pentane	triplicate
5				USI IC-1065	0.08	0.05	0.005(?)	0.21	0.45	methane	duplicate
					% CO_2*	% O_2*	% CO*				
4	3.09	2380	132363		0.37 0.62	0.02 0.07+	0.05 0.07	0.00	3.8	ethane	duplicate; first sample of 1 l. or more
2	2.40	730	132366		0.06 0.05	0.02 0.008	0.00 0.002	0.12	0.14	ethane(?)	duplicate
2	0.45	0	132369		0.06 0.02	0.02 0.05	0.00 0.01	0.22 total		—?—	duplicate
4	0.57	790	132370		0.37 0.34	0.02 0.01	0.05 0.01±	2.49 total		—?—	duplicate
2	0.91	298	132372		0.06 0.05+	0.02 0.005	0.00 0.00	0.23 total		—?—	duplicate; acetaldehyde added
2	6.97	2200	132373		0.06 0.05	0.02 ≤0.01	0.00 0.00	0.09	0.18	methane	single
3	6.43	1915	132375		0.10 0.11	0.02 0.02	0.00 0.009	0.16	0.32	ethane(?)	single
5	4.29	745	132376		0.08 0.07	0.05 0.009	0.005(?) 0.00	0.10	0.63	methane	single

Code: Math—The Mathieson Co., Inc.
OC—Ohio Chemical and Surgical Equipment Co.
C and C—Carbide and Carbon Chemicals Corp.
USI—United States Industrial Chemicals, Inc.

* Top, before irradiation (no removal by distillation and no addition to ethylene unless noted).
Bottom, after irradiation.

Discussion of Polymerization of Ethylene

In many of the early runs the time of radiation was approximately the same as what was later found to be the induction period. The amounts of product from these runs varied from practically nothing to very appreciable quantities. Before the length of time of the induction period was ascertained, it was thought that impurities in the ethylene might be responsible for the inconsistent results (see Table 1). The ethylene was analyzed immediately upon removal from the storage cylinder, after charging to the reactor but before irradiation, and upon removal from the reactor after irradiating (Table 2). Only small amounts of impurities, such as carbon monoxide, carbon dioxide, oxygen, paraffin hydrocarbons, and nitrogen, were found. There was no apparent correlation between these impurities and the variation in the amount of polymer produced by radiation.

The influence of solvents or other materials which might have been present accidentally in those runs in which appreciable polymerization occurred was checked by adding the following materials successively to separate batches of reacting ethylene: acetone, acetaldehyde, air and acetone, air and water, carbon dioxide, sulfur dioxide. None of these had any appreciable effect on the polymerization of ethylene. The addition of sulfur dioxide did result in the production of a white powder which proved to have a sulfur content close to that of the equimolar addition product of sulfur dioxide and ethylene (Figure 2). Matthew and Elder (*15*) and Snow and Frey (*17*) reported similar reactions between sulfur dioxide and olefins under ultraviolet light. In some runs in which noncondensable gases were vented from liquid ethylene before charging to the reactor, the initial rate of reaction was increased to some extent though not enough to explain the discrepancy in yields.

The presence of the long induction period and the explanation of the wide variation in yield of polymer were revealed when several runs were made with long periods of radiation. What was earlier an apparent inconsistency in results is now readily understandable from an examination of Figure 2, for up to about ½ megarep little or no reaction occurs, and runs made in that range cannot give consistent yields of product.

Average values of dose rates used in these studies varied from about 30 kilorep/hr. to about 90 kilorep/hr. The values given for G in Figure 2 should be regarded as relative rather than absolute, since all determinations were made in the same equipment with similar procedure.

No consistent effect of pressure on G value could be noted. Elevated temperatures were investigated only briefly, but preliminary results indicated that considerably increased rates of polymerization would result in irradiated systems at temperatures of 200° to 400° F., as compared with those obtained at room temperature.

Evaluation of the Polyethylene Product

The polyethylene obtained as a result of gamma irradiation of ethylene was subjected to a brief program of evaluation. Most experimental work was concerned with determinations of solution viscosity, melt viscosity, density, and tensile strength. Melting points of some samples were also determined, molecular weights were estimated from the determinations of viscosities of solutions and of melts, and crystallinity was estimated from determinations of density.

Lind (*12*) has shown that in many gaseous systems approximately one molecule reacts per ion pair formed in the system. In the irradiation of ethylene a variable number of molecules, usually much greater than one, react for each ion pair formed; evidently the polymerization of ethylene is a chain reaction. For the following calculation it is assumed that one chain is initiated for every ion pair formed, that all chains are of equal length, and further that the formation of each ion pair requires 32.5 electron volts of energy, a value (*16*) approximately correct for gases at one atmosphere. The densities of ethylene under the conditions of reaction were greater than at 1 atm. and therefore the energy required per ion pair may be different from the value given. The G value which is based on 100 electron volts may therefore be divided by three to give the approximate number of molecules reacted for each ion pair formed, and this result may then be multiplied by the molecular weight of the monomer in order to estimate the average molecular weight of the polymer.

Because the molecular weight is directly proportional to the G value, it is advantageous to consider the properties of the polyethylene as functions of the G value. The results of most determinations can be correlated against the G value better than they can against dose, although the G value has been shown to be a function of dose. The data in Figure 2 indicate that the G value was about 0.1 to 1.0 until about 0.5 megarep had been received. The G value then increased rapidly with increasing dose until it reached a nearly constant value of about 2,000 for doses of about 3 to 7 megarep.

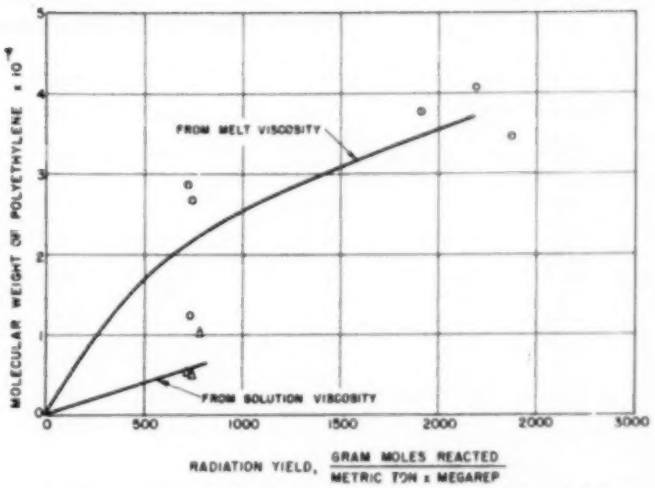

Fig. 3. Molecular weight as function of radiation yield of polyethylene.

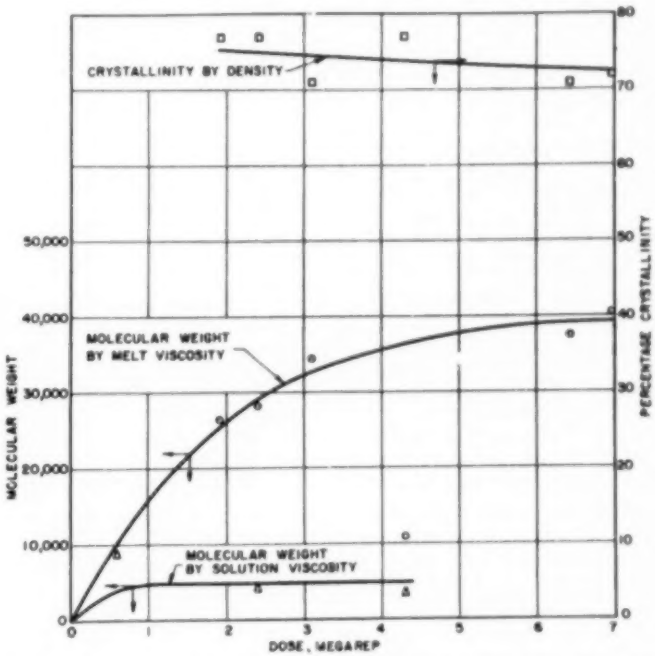

Fig. 4. Molecular weight and crystallinity as functions of radiation dose for polymerization.

Experimental

All the samples of polyethylene which were produced were white. Some were fluffy powders and others were tough, coherent masses.

Portions of each of the samples of polyethylene which occurred in yields of 4 g. or more were molded into sheets as an operation preliminary to further examination. A two compartment mold was used, one compartment at a time. Samples were placed between aluminum foil in the mold, preheated to 300° F., pressed to 1,000 lb./sq.in., and cooled to about 125° F. under pressure. The resulting sheets were $2.5 \times 4 \times 0.025$ in. All such sheets had the characteristic milky, translucent appearance of polyethylene. The sheets molded from the powders were brittle but those from the tough reaction products were also tough.

Molecular weights were estimated from viscosities of solutions measured as follows. Solutions were prepared in concentrations of 0.01% and of 0.125% by weight in tetralin. Viscosities of these solutions and of the tetralin were measured in modified Ostwald pipettes at 212° F. Specific viscosities were calculated and divided by the respective concentrations. The resulting ratios were plotted as a function of the concentration of polymer, and the curves were extrapolated to zero concentration to give intrinsic viscosity. Intrinsic viscosity was assumed to be directly proportional to molecular weight. The concentration was computed in units of gram moles of monomeric ethylene per liter of solution. The constant of proportionality was computed on the basis that the molecular weight of Bakelite DYNH was 20,000, as given by Dienes and Klemm (*6*). Tani (*18*) also reported on intrinsic viscosities of polyethylene in tetralin.

The method of Dienes and Klemm (*6*) was used to estimate molecular weights from melt viscosities. Viscosities were measured in a parallel-plate plastometer with an attached dial gauge reading to 0.01 mm., and the entire assembly was placed in an oven. Temperatures of 248° F. and 266° F. were used. The samples were placed between sheets of aluminum foil about 1½ mils thick. The thickness of the sheets of foil was measured in the plastometer before each determination.

Table 3—Properties of Polyethylene Produced

Experiment No.	Dose, Megarep	Radiation Yield, A	Melting Point, °F. Lower/Upper	Density g./cm.³	Ultimate Tensile, lb./sq.in.	Elongation, per cent at rupture	Crystallinity per cent	Molecular Weight by Melt Viscosity	Molecular Weight by Solution Viscosity
132250	1.55	95	219/226						
132268	0.61	37	216/225						
132269	0.58	71	205/217						
132276	0.60	63	207/214						
132281	0.54	52	196/205						
132297	1.91	750	241/244	0.951	450	4	77	26,300	insol.
132362	0.37	28	234/235						
132363	3.09	2400	248/689	0.941	2200	42	71	34,400	insol.
132366	2.40	730	210/248	0.951	770	2	77	28,100	4200
132369	0.45	0.1							8800
132370	0.57	790	203/252						insol.
132372	0.91	298	199/207						insol.
132373	6.97	2200	234/720	0.943	2100	29	72	40,500	insol.
132375	6.43	1900	241/610	0.941	2300	79	71	37,300	3700
132376	4.29	745	241/244	0.951	630	3	77	11,900	20,000
Bakelite DYNH				0.921	1500	550	61	21,800	assumed

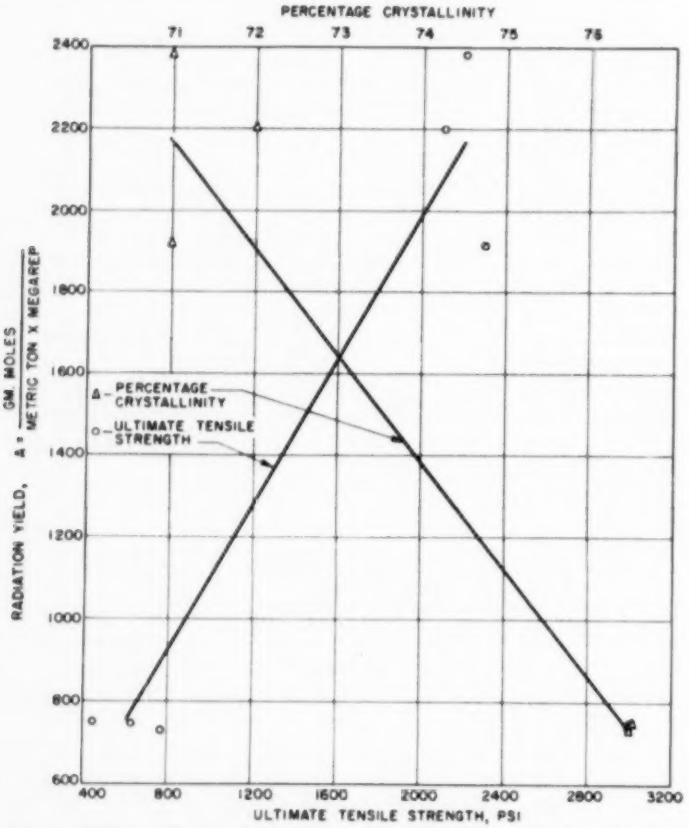

Fig. 5. Crystallinity and tensile strength as functions of radiation yield for polyethylene.

Crystallinity was estimated from the density (*9*). Density was determined by weighing directly in water after degassing the immersed sample under reduced pressure.

Tensile properties of the polyethylene were examined by the following procedure. Specimens for testing were cut from the molded sheets by means of a die. The resulting specimens were 0.079×0.025 in. in the smallest cross section. The narrowest section was 1½ in. long. Tension was applied in a Gardner-Parks testing machine (*7*).

Melting points were determined on a melting-point bar of the design of Dennis (*5*).

Discussion

The results of evaluation of the properties of the radiation polymerized polyethylene are summarized in Table 3, the molecular weight is plotted as a function of radiation yield in Figure 3, and the molecular weights and crystallinities are plotted as functions of dose in Figure 4. The values obtained were assumed to be weight average molecular weights (Table 3) although differences in crystallinity and cross-linking between these samples and thermally polymerized samples may make the relationship less valid.

Determinations of molecular weight by melt viscosity may be subject to similar criticism. As shown in Figures 3 and 4 the molecular weights determined by solution viscosity do not agree well with those determined by melt viscosity. Neither do the molecular weights from solution viscosity appear to display any regular variations with dose or with G value, in contrast to the regular behavior of molecular weights from melt viscosities.

Values of crystallinity are plotted as a function of radiation yield in Figure 5. The crystallinities varied from about 77% for samples of low radiation yield to about 71% for samples of high radiation yield, all these samples being of considerably higher crystallinity than was the Bakelite DYNH, which had a crystallinity of about 61%. It is possible that radiation-polymerized samples were of higher crystallinity than the thermally polymerized sample of DYNH because the temperature of polymerization was lower for the radiation-polymerized samples. The samples of low radiation yield would be expected to be more highly crystalline than those of high radiation yield, since radiation yield has been shown to increase with dose (Figure 2). Cross-linking and branching would probably also increase with dose, and both cross-linking and branching decrease crystallinity.

Tensile properties are reported in terms of stress as a function of strain (Figure 6). Ultimate tensile stress as a function of radiation yield is plotted

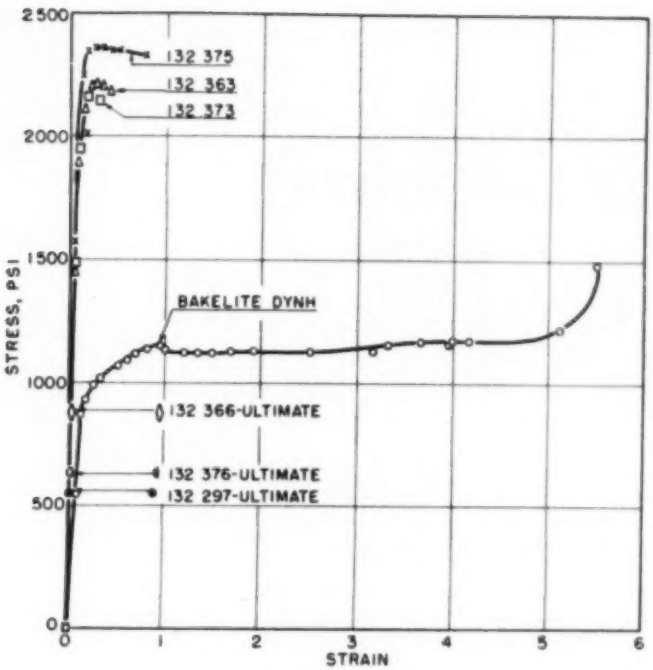

Fig. 6. Stress-strain plots for test specimens of polyethylene.

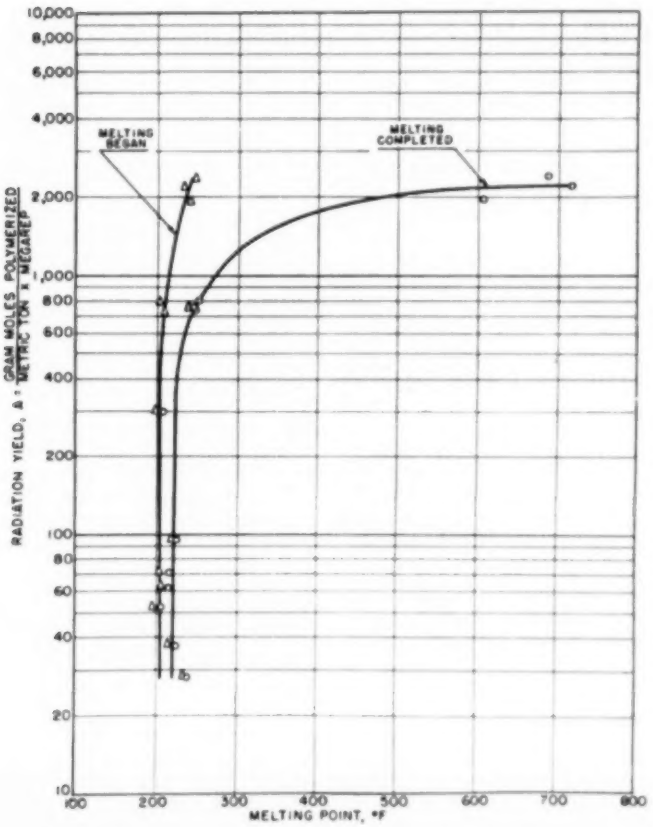

Fig. 7. Melting points as functions of radiation yield of polyethylene.

in Figure 5. The ultimate tensile stress increased markedly with radiation yield and consequently with dose.

Melting points are plotted as a function of radiation yield in Figure 7, curves being given for both the upper and the lower ends of the melting-point range. The higher melting points indicate higher degrees of cross-linking as a result of the higher doses of radiation and are thus in conformity with the results of the other determinations mentioned.

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THE HOMOGENEOUS REACTOR EXPERIMENT

a chemical engineering pilot plant

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The Homogeneous Reactor Experiment—a nuclear pilot plant for the production of electricity with an aqueous solution of uranium as fuel—has been operated by the Oak Ridge National Laboratory over a two-year period. The heat-producing chain reaction occurred in an 18-in. diam. sphere, and heat was removed by pumping the liquid fuel through a U-tube heat exchanger where steam was generated and fed to a small turbine-generator unit. When the reactor was operated at 1,000 kw. heat output at 250° C. and 1,000 lb./sq.in., a sufficient quantity of 200 lb./sq.in. steam was produced to generate 140 kw. of electricity.

The inherent safety of the reactor, as a result of its large negative temperature coefficient, was demonstrated by increasing the power by a factor of 10^{+6} in 1 sec. Although no mechanical control devices were used, a safe equilibrium condition was reached in 100 ms.

The many attractive features of completely liquid systems for nuclear reactors have intrigued chemical engineers since the first chain reaction in 1942. However, because of such difficult and long-term problems as corrosion, fuel chemistry, and decomposition of liquids under intensely radioactive conditions, the development of liquid-fuel reactors for power production proceeded slowly until 1950. In that year the Oak Ridge National Laboratory undertook the task of designing, building, and operating a pilot plant model liquid-fuel reactor, the Homogenous Reactor Experiment (Figure 1). The purpose of this reactor was to investigate the chemical feasibility of maintaining a nuclear chain reaction with a liquid fuel at temperatures and powers sufficiently high for the production of electricity from the thermal energy released. Specifically, it was designed to operate with a full power heat release of 0.6 to 3.5 million B.t.u./(hr.) (200 to 1,000 kw. of heat), a maximum fuel solution temperature of 482° F. yielding, after heat exchange, a saturated steam pressure of about 200 lb./sq.in.

The Reactor Fuel System

Nuclear energy is released in the reactor core, a stainless steel sphere only 18 in. in diam., through which is circulated 100 gal./min. of enriched uranyl sulfate dissolved in distilled water. More than 90% of the uranium is the fissionable isotope ^{235}. The temperature rise of the solution passing through the core as a result of the chain reaction, is about 72° F. at the higher design level of 1,000 kw. The liquid is discharged from the core at a temperature of 482° F., and is cooled to 410° F. by evaporating water from the shell side of a U-tube heat exchanger, thus generating about 3,000 lb./hr. of 200 lb./sq.in. steam. A "canned rotor" centrifugal pump returns the fuel to the core to be reheated. Fuel consumption for continuous operation at 1,000 kw. heat output is only 0.002 lb./day (Figure 2).

A total pressure of 1,000 lb./sq.in. is maintained in the fuel system by heating a small volume of fuel to 545° F. in a pressurizer chamber directly above the sphere. The 1,000 lb./sq.in. total pressure, which is several lb./sq.in. greater than is required to prevent boiling of the fuel solution, is necessary to minimize the volume of decomposition gases.

The Reflector System

In any small reactor system the quantity of fuel required can be reduced by surrounding the fuel mass with a material, descriptively called the reflector, which increases the supply of neutrons available for fissioning. In the HRE, the reflector is a 10 in. layer of D_2O surrounding the core vessel. Demineralized H_2O may be used in later experiments, although its lower efficiency as a reflector makes it necessary to increase the fuel charge to maintain the same operating temperature. The heavy water is normally pressured with helium to within ±100 lb./sq.in. of the fuel pressure in order to minimize stresses in the 3/16 in. wall of the spherical fuel container. Both the reflector and the concentric core are contained in an outer pressure vessel which is of forged steel, 39-in. I.D. with a 3-in. thick wall. A 24-in. 1,500 lb./sq.in. standard ring joint flange fitted onto a short neck at the top of the vessel allows removal of the inner core.

In order to limit thermal stresses and to reduce corrosion of the steel vessel, the reflector temperature is regulated near 350° F. About 50 kw. of heat leakage from the fuel core to the reflector liquid is removed by circulating the heavy water with a 30 gal./min. "canned rotor" pump through a reflector cooler which acts as a boiler feed-water preheater. There is in this high pressure circulating loop a jet, the suction of which draws a continuous stream of gas from the vapor space above the reflector to a catalytic recombiner so that the concentration of deuterium and oxygen gases in this

vapor space can be kept below explosive limits.

Some measure of nuclear control is exerted by the level of the reflector. The level can be lowered by draining liquid through a valve to storage tanks, or raised by starting a feed pump. This pump, which employs a double diaphragm with check valves, has a capacity of approximately 2 gal./min. against 1,000 lb./sq.in. Its intake is connected to atmospheric pressure tanks located below the reactor. These tanks also serve as de-gas chambers for the reflector liquid which is discharged from the pressure vessel. Helium, water vapor, and D_2 and O_2 gas liberated here pass upward through a condenser to a small low-pressure catalytic bed where the O_2 and D_2 gases are recombined to D_2O. Cold traps operated at $-20°$ F. are included in the reflector system vent lines to prevent the loss of D_2O or its contamination with H_2O vapor.

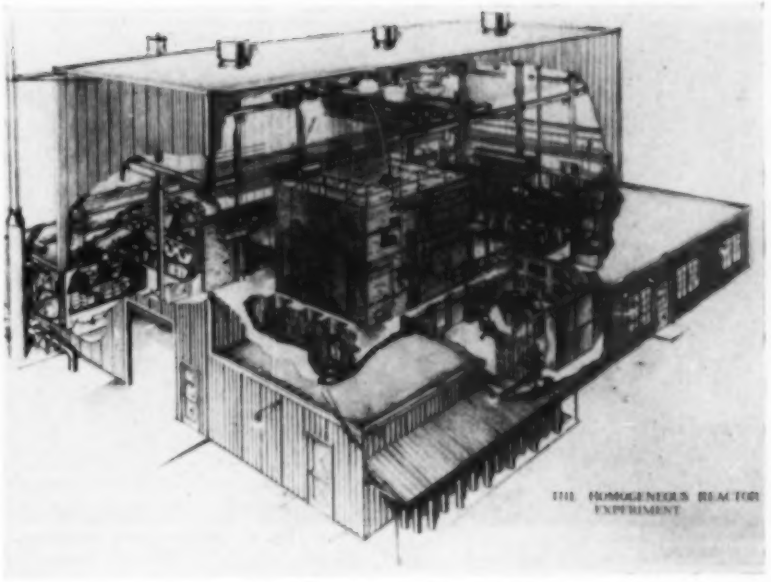

Fig. 1. The homogeneous reactor experiment.

The Fuel Off-Gas System

When the reactor is operating, the fuel solvent (H_2O) is decomposed by the energy of fission to yield a stoichiometric mixture of hydrogen and oxygen gas at a rate of 10 cu.ft./min S.T.P. In addition to this large volume of decomposition gases, there is also produced a very small volume (20 cc./day) of intensely radioactive fission gas. If these gases were not removed and replaced by more liquid, excessive pressures would soon result, and, since virtually all of this gas is liberated within the core, the displacement of fuel solution by the gas would make it impossible for the chain reaction to continue. For this reason, the gas is continuously separated from the fuel in the core by injecting the main circulating stream tangentially near the equator of the sphere, which causes the fluid to rotate and form a vertical cylindrical vortex approximately ¼-in.-diam. The centrifugal action of the rotating fluid serves to separate the decomposition and fission gases from the liquid to the vortex, the axis of which is aligned with the fuel outlet. An obstruction, with a central opening in the fluid outlet, allows the removal of gas from the vortex. This gas, in addition to about 0.8 gal./min. of the fuel solution, is passed through a countercurrent, double-pipe heat exchanger which is partially cooled by 0.8 gal./min. flow of fresh make-up liquid being pumped back to the core. The cooled mixture of gas and liquid is then throttled through a valve into a gas separator which is connected to the fuel solution storage tanks. The gas-steam mixture rises from the gas separator to a condenser immediately preceding a flame recombiner so that the gases leaving the condenser are combustible and may be reunited to water in the flame of the recombiner (Figure 2).

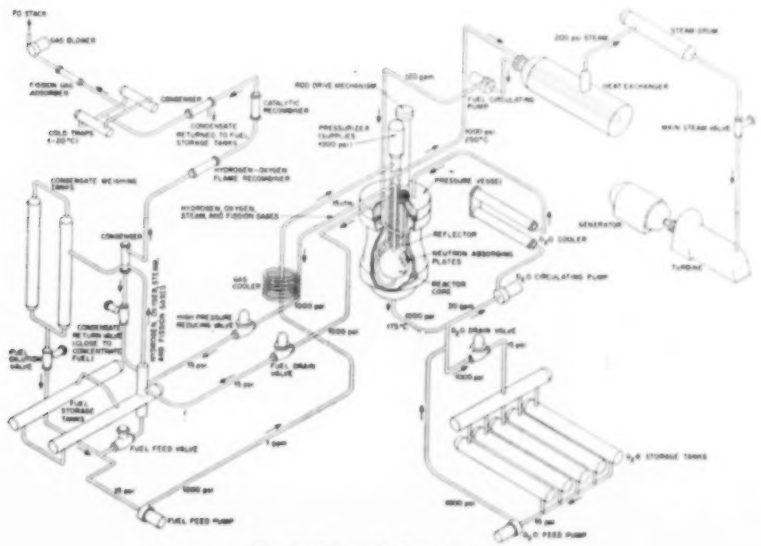

Fig. 2. Schematic flow diagram.

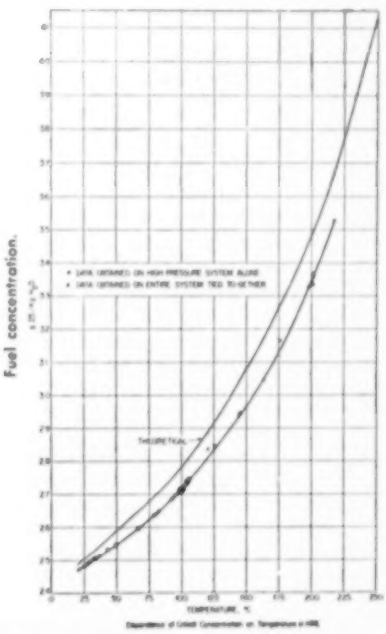

Fig. 3. Dependence of critical concentration on temperature in HRE.

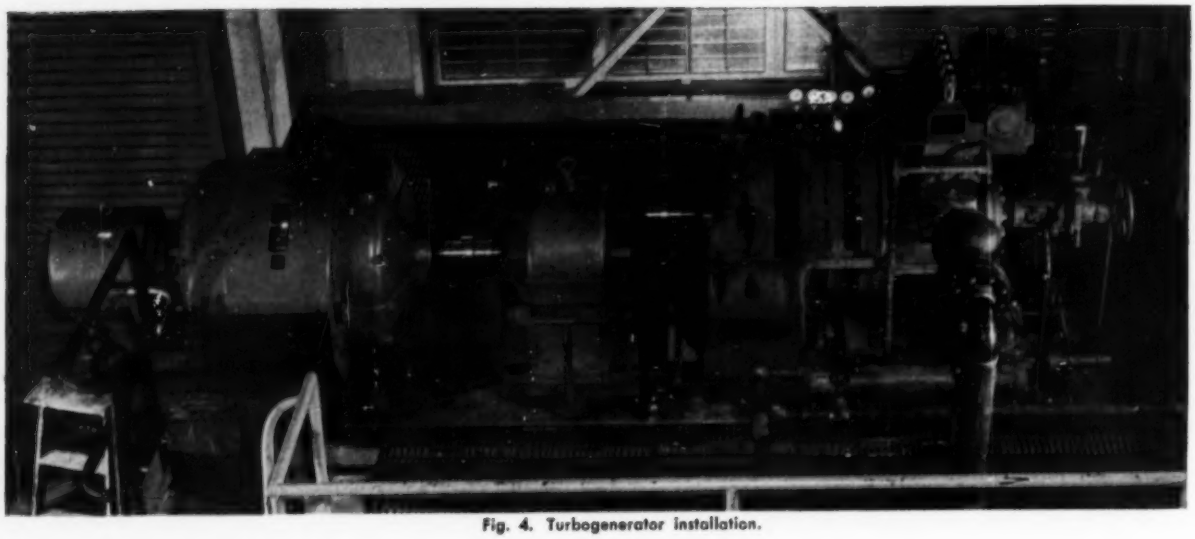

Fig. 4. Turbogenerator installation.

The flame recombiner is best described as an oversized Bunsen or Meeker burner enclosed in a water-jacketed cylinder. In the HRE no attempt is made to use this 40 kw. of high-temperature heat, although in larger scale reactors this energy might be used to superheat steam about 70° F.

The exit gases from the flame recombiner contain only fission products and small amounts of unrecombined hydrogen and oxygen. They are passed through a catalytic recombiner which contains a platinized alumina catalyst to eliminate the traces of hydrogen and oxygen. Also, the catalytic bed is used to react the entire gaseous output at low reactor powers where insufficient gas is being liberated to maintain a steady flame at the burner of the flame recombiner. The catalytic bed is followed by a condenser and cold traps to prevent the loss of water from the system. The gas stream at this point is composed almost entirely of the highly active fission gases, mainly xenon, krypton, and their decay products. The activity of these gases is many orders of magnitude greater than the activity which can be discharged directly to the atmosphere without the construction of a very expensive stack; therefore it is desirable to provide some inexpensive means of storage for the dissipation of the radioactivity. This is accomplished by absorbing the gases onto water-cooled activated carbon beds which are buried underground outside the reactor building. It is estimated that the equilibrium activity of the gases held on the carbon bed is 400,000 curies. (One curie equals 3.7×10^{10} disintegrations/sec.,

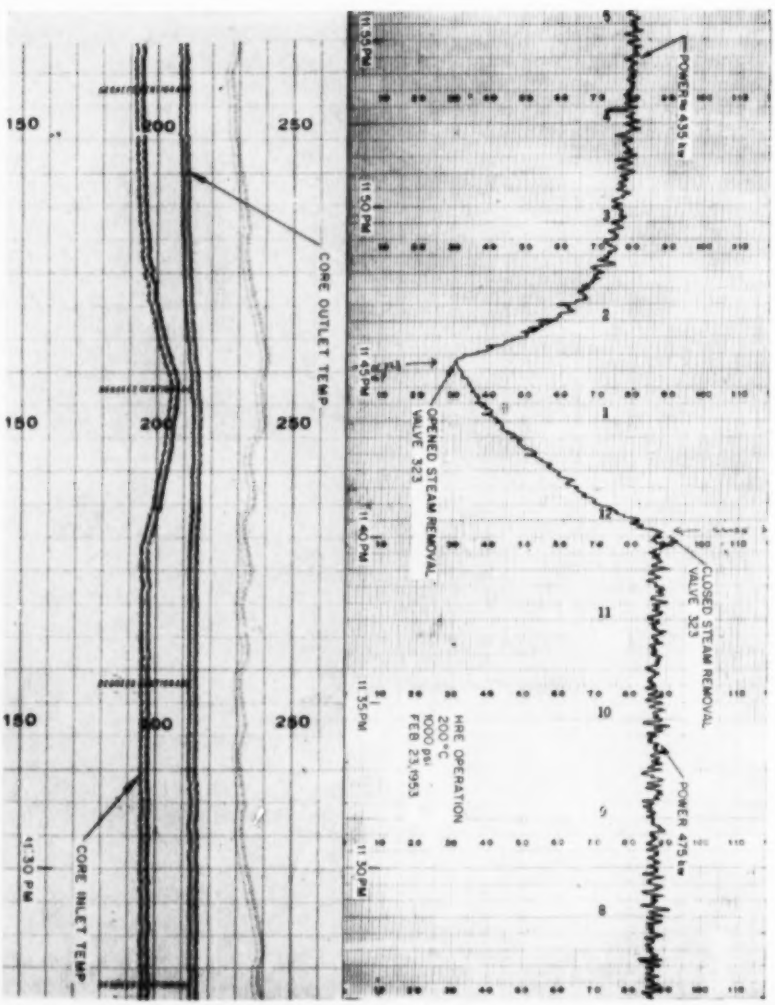

Fig. 5. Response to power demands.

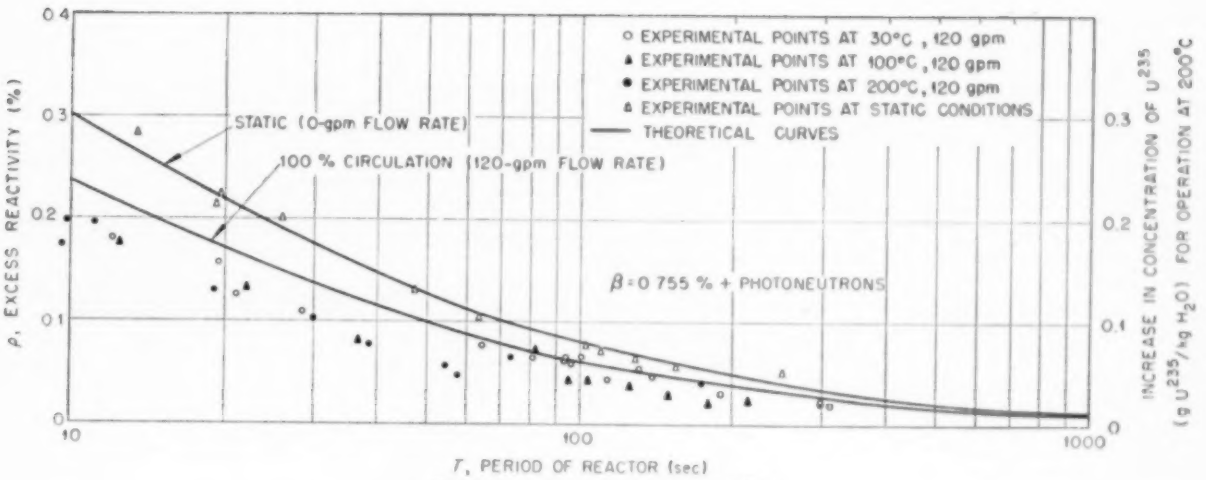
EXPERIMENTAL POINTS AT 30°C, 120 gpm
EXPERIMENTAL POINTS AT 100°C, 120 gpm
EXPERIMENTAL POINTS AT 200°C, 120 gpm
EXPERIMENTAL POINTS AT STATIC CONDITIONS
THEORETICAL CURVES
STATIC (0-gpm FLOW RATE)
100 % CIRCULATION (120-gpm FLOW RATE)
β = 0.755 % + PHOTONEUTRONS
ρ, EXCESS REACTIVITY (%)
INCREASE IN CONCENTRATION OF U235 (g U235/kg H2O) FOR OPERATION AT 200°C
T, PERIOD OF REACTOR (sec)

Fig. 6. Reactor period vs. excess reactivity.

which is the rate of decomposition of one gram of radium.)

The adsorption efficiency of the charcoal, even at ground temperature, is good enough to prevent a discharge of activity greater than a few curies/day. However, even this amount of activity must be diluted so that the atmospheric concentration at ground level is not greater than 10^{-13} curies/cc. of air. Dilution is accomplished by feeding the active gas into a 1,000 cu.ft./min. ventilating air stream from the reactor shield and then to a 100-ft. high stack. During operation the gaseous activity inside the stack barely exceeds breathing tolerance.

Fuel Concentration Control

The condensate which was removed from the vapor-gas mixture upstream of the recombiner is returned either to the fuel storage tanks or to weighed holding tanks. The accumulation of water in the holding tanks provides a means of increasing the concentration of fuel in the storage tanks underneath the reactor. Since fuel is being pumped continuously from the storage tanks to the high pressure system by means of a duplex-diaphragm-type pump at a rate of 0.8 gal./min., it is possible to vary the concentration of the fuel which is circulating through the reactor. (Figure 3 shows how the core temperature varies with fuel concentration—in g./kg.H_2O.) Furthermore, since the operating temperature of the core is controlled by the fuel concentration as shown in this figure, the operator has a convenient means of adjusting the solution temperature to the desired level. This feature of variable concentration is employed during start-up of the reactor when the concentration must be changed by large amounts, and also during steady operation for small changes in temperature. When sudden dilution of the fuel is desired as in the case of a complete shutdown, the condensate holdup tanks may be quickly emptied through a drain valve into the fuel-storage tanks.

The steep slope of the curve—i.e., the high negative temperature coefficient—is a feature which is extremely important from safety and power demand standpoints. For instance, a temperature rise of only 15° C. is necessary to overcome a reactivity increase of 1%, an amount considered very dangerous in most solid fuel reactors.

Power Removal

The steam generated in the fuel heat exchanger is fed to a conventional multistage condensing turbine-generator rated at 312 kva. With the reactor operating at 1,000 kw. and 250° C., a sufficient quantity of 200 lb./sq.in. steam is produced to generate about 140 kw. of electricity. Steam leaving the heat exchanger is first passed through a time-delay drum with a radioactivity monitor at the inlet and a quick closing valve at the outlet, to prevent the escape of activity into the turbine system in the event of boiler tube failure. Small feed pumps return the condensate from the turbine to the boiler (Figure 4).

Upon increase in generator load, the turbine governor opens the turbine throttle valves, increasing the steam demand, lowering the steam pressure and

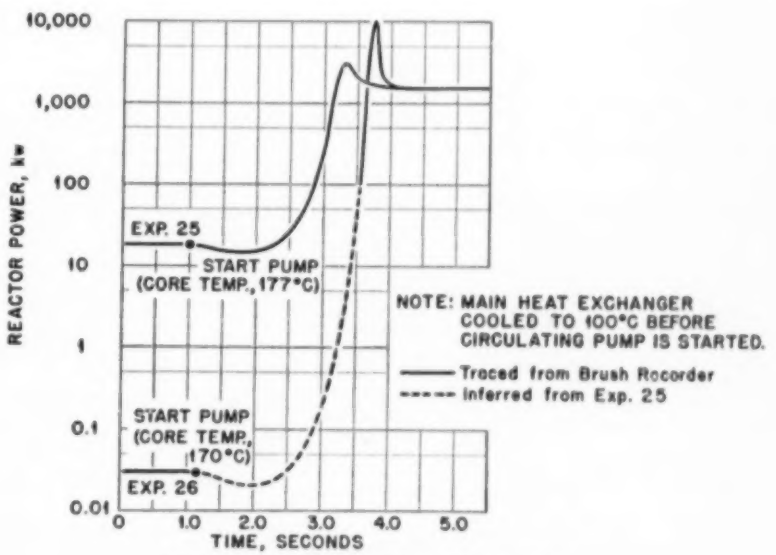
REACTOR POWER, kw
TIME, SECONDS
EXP. 25
START PUMP (CORE TEMP., 177°C)
START PUMP (CORE TEMP., 170°C)
EXP. 26
NOTE: MAIN HEAT EXCHANGER COOLED TO 100°C BEFORE CIRCULATING PUMP IS STARTED.
Traced from Brush Recorder
Inferred from Exp. 25
POWER RESPONSE OF HRE DURING REACTIVITY INCREASE OF 0.8% PER SECOND

Fig. 7. Power response of HRE during reactivity increase of 0.8%/sec.

temperature, reflecting itself into increased cooling of the uranium solution, which automatically increases the reactivity of the core and completely compensates for this increased load. The transient response of the system is shown in Figure 5. The steam pressure, nuclear power, and core inlet temperatures are plotted as a function of time following a quick change from power operation to no power operation and the reverse cycle.

Figure 6 gives the time required for the reactor power to change by a factor of e as a function of excess uranium in the core over its equilibrium condition. The curve and Figure 5 explain why the reactor is completely self-stabilizing and responsive to power demands without other controls. This feature is quite different from practically all other nuclear reactors so far constructed. Whereas their control devices regulate their rate of change of power level, in this machine any nuclear control device merely regulates the equilibrium temperature of operation after an initial transient caused by this change. The power of operation is determined solely by the rate of heat removal.

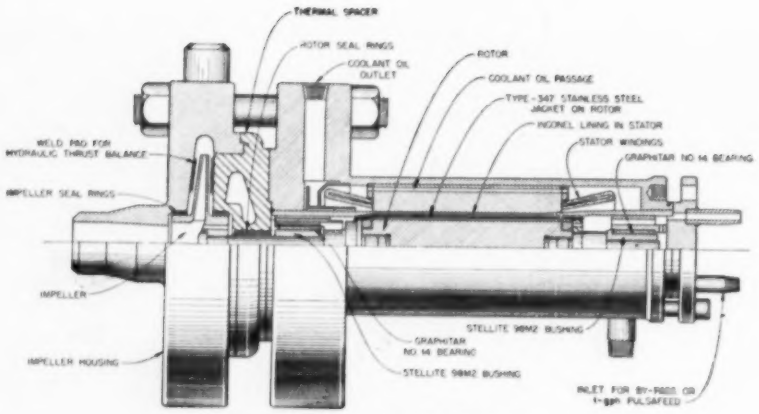

Fig. 8. "Canned rotor" circulating pump.

Nuclear Safety

Although operating experience has verified early predictions of the inherent safety of this reactor—that is, its stabilizing feature—at the time of design it was considered judicious to incorporate conventional safety devices in the reactor for protection against potentially dangerous situations which might arise during low power, experimental operation, and until the dynamic stability has been demonstrated by experiment. Safety measures, in the order of their automatic action as installed to limit reactor power or doubling time, are:

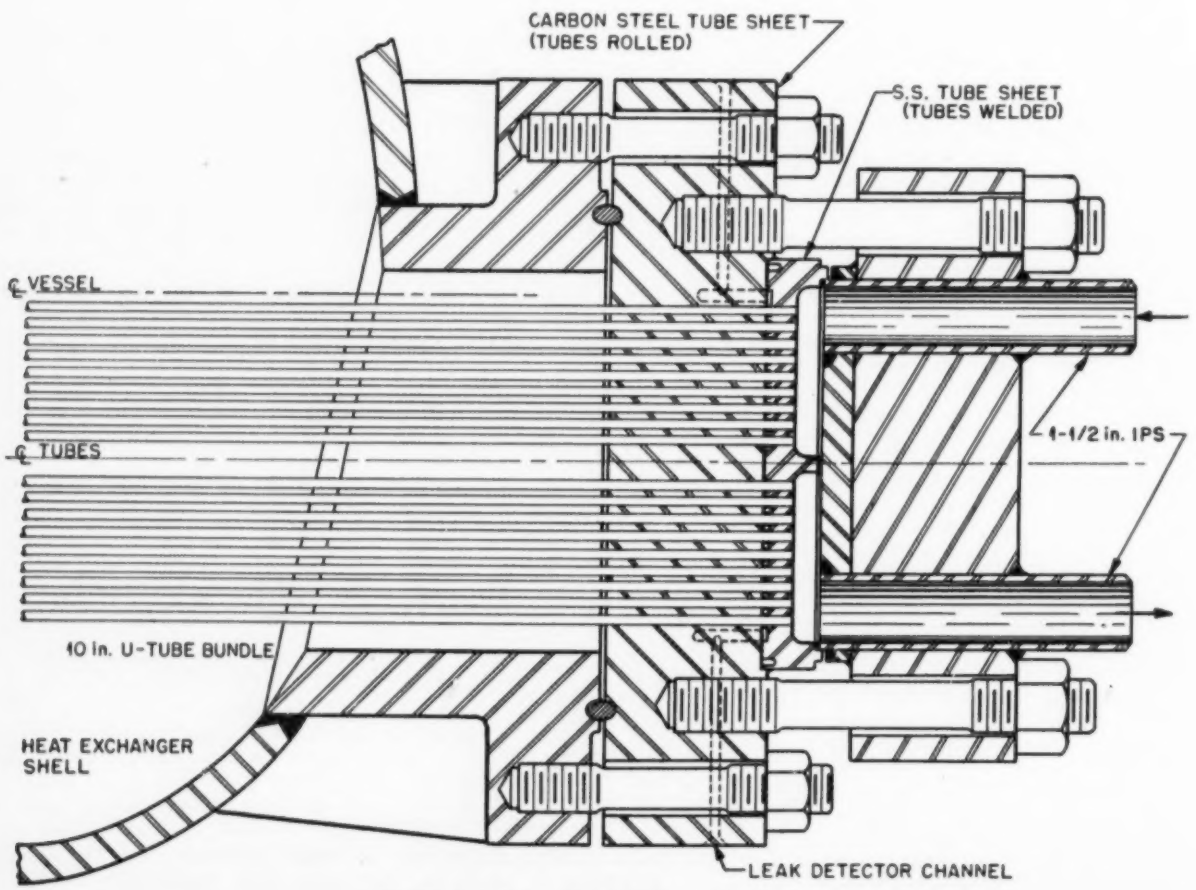

Fig. 9. Leak detector—heat exchanger tube sheet.

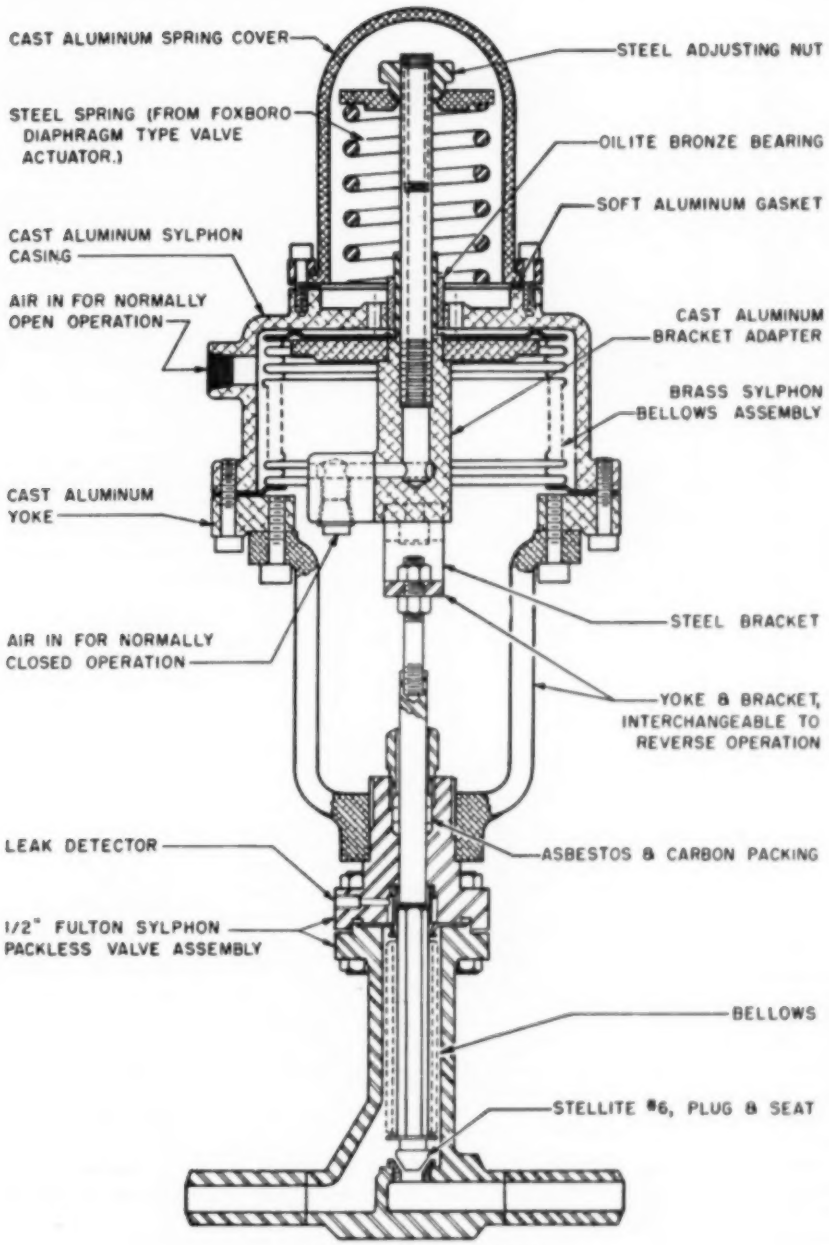
CAST ALUMINUM SPRING COVER
STEEL ADJUSTING NUT
STEEL SPRING (FROM FOXBORO DIAPHRAGM TYPE VALVE ACTUATOR.)
OILITE BRONZE BEARING
SOFT ALUMINUM GASKET
CAST ALUMINUM SYLPHON CASING
AIR IN FOR NORMALLY OPEN OPERATION
CAST ALUMINUM BRACKET ADAPTER
BRASS SYLPHON BELLOWS ASSEMBLY
CAST ALUMINUM YOKE
STEEL BRACKET
AIR IN FOR NORMALLY CLOSED OPERATION
YOKE & BRACKET, INTERCHANGEABLE TO REVERSE OPERATION
LEAK DETECTOR
ASBESTOS & CARBON PACKING
1/2" FULTON SYLPHON PACKLESS VALVE ASSEMBLY
BELLOWS
STELLITE #6, PLUG & SEAT

Fig. 10. High pressure valve.

1. Two magnetically coupled safety plates, worth about 45 g. of uranium, which by falling in 0.01 sec. cause the reactor temperature to be lowered from 250° C. to approximately 243° C.
2. The reflector may be dumped.
3. The fuel may be diluted. (This is the normal shutdown procedure.)
4. The steam extraction may be stopped by closing either a steam valve or the turbine governor.
5. The fuel solution may be drained to the noncritical geometry tanks below.

Experiments have since demonstrated that the reactor itself is extremely fast acting with respect to limiting power surges and has led to the belief that any mechanical control device is unnecessary.

Experiments have been performed in which uranium has been suddenly introduced at a rate of 75 g./sec. Doubling times as short as 30 ms. were attained. The power rose from 30 watts to 11×10^6 watts in 1 sec. and returned to normal in another 0.1 sec. (See Figure 7). In this experiment the worst combination of circumstances was imposed on the reactor. It was successfully demonstrated that the HRE is sufficiently stable, from a nuclear point of view, to withstand transients greater than those to be expected from operating errors.

Chemical Stability and Corrosion

The only statement that can be made on this point is that the fuel and its 347 stainless-steel container were sufficiently rugged to withstand a protracted test period. More will be known now that the machine is being disassembled for

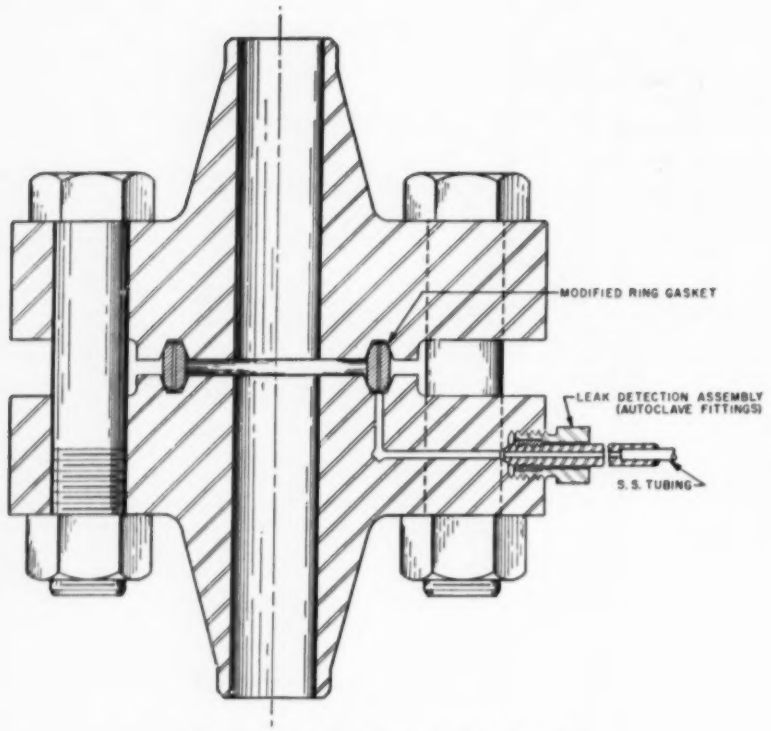

Fig. 11. Ring joint with provision for leak detector.

examination. The gross corrosion rate was followed by periodic analysis for nickel.

Leak Prevention

A major problem in a system such as this is to maintain absolute leak tightness in all components. The radioactivity of the solution during operation is about 30 curies/cc. Twenty-four hours after shutdown the activity is about 3 curies/cc. With these high activities, the total leakage from the system must be kept below 1 cc./day. A much better performance than this has been attained through the use of canned rotor pumps, double-tube sheet exchangers and bellows-sealed valves, cross sections of which are shown in Figures 8, 9, and 10.

All welded joints were made with extraordinary care and tested by several nondestructive methods before being approved for use. Flanged joints were assembled with stainless-steel ring gaskets of oval cross section, and each joint contains a simple leak detection device for constant monitoring. (See Figure 11). In addition, the ventilating air which flows through each equipment compartment is monitored constantly with radiation detection devices. Although several leaks were experienced in the start-up phases, no leakage was found during the final 12-month period.

Shielding

As in all nuclear reactors, personnel must be protected from the high radiation levels which exist in the vicinity of the reactor core. In the HRE, this protection was provided by a 7-ft. thick shielding wall of high density concrete. An increase in the density of the concrete to 3.5 resulted from the use of barium sulfate ore as the aggregate material. The shield is a departure from most reactor shields in that it was constructed of loosely stacked block with only the outer 16-in. layer of blocks being mortared. The use of block in this manner is desirable in an experimental reactor because it allows flexibility in revising the shielding arrangement as shown in Figure 1.

Costs

The total construction costs of this reactor was $1,100,000 which does not include the cost of fuel and heavy water. Table 1 is a summary showing the cost of various parts of the system.

Maintenance

The maintenance of nuclear reactors is greatly complicated by the radioactivity of the parts on which work must be done. It is often necessary to decontaminate equipment and to provide temporary protective shielding before repair work can be done. Furthermore, in most cases the repair work must be done with long-handled tools which make the job even more difficult.

Table 1—HRE Construction Cost Summary *

	Total	% Of Total
Building	300,414	27.5
Fuel and reflector equipment and piping	419,122	38.2
Instrumentation	192,786	17.6
Shield	106,305	9.7
Power system	75,535	6.9
Total construction cost for HRE	1,094,162	100.0

* These costs include material, labor, and allocated overhead.

By the use of decontamination, shielding, and extension tools, it has been possible to make a number of major repairs in radiation fields as high as 200 r/hr., without over-exposing personnel beyond accepted tolerances. The main circulating pump has been replaced or repaired three times under such conditions and the diaphragm feed pumps twice. In fact, in no case of a breakdown has it been impossible to make the necessary repairs, although a great deal of ingenuity was necessary in some instances. For example, mirrors, binoculars, and a Polaroid-Land camera were found to be invaluable tools.

Operating Hours

During the 24-month period in which HRE was in operation, liquid was circulated for a total of 4,498 hr. The reactor was critical a total of 1,950 hr. and operated above 100 kw. for 720 hr. The maximum power level attained was 1,600 kw.

Present Status

The HRE has been shut down for dismantling which is nearly completed. The reasons for dismantling are

1. Although the reactor was operable, almost all the data desired had been collected except for a detailed examination of the interior for corrosion and radiation damage.
2. The seat of the main dump valve had started to leak excessively. To continue would have meant replacement of this valve, which would have been about a month's work.
3. The building and equipment were desired for more advanced pilot plant experiments.

Summary

Except for the precautions against excessive radiation exposure, chemical engineers will recognize that the problems encountered, and the equipment provided, differ little from those of a standard high pressure chemical pilot plant in which one carries out a highly exothermic reaction with a negative rate coefficient of temperature.

On the whole it is felt that this has been a highly successful experiment — one which incorporated many more novel and useful features than have been described. Also, it has adequately demonstrated the basic feasibility of the fluid fuel concept for nuclear power reactors.

Radioactive Wastes

treatment, use, disposal

W. A. Rodger

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In recent years the building of an industry producing by-product radioactive wastes has required, right from the beginning, complete control of their disposal. Mistakes could be disastrous, both immediately and for a long period of years. As the author of this paper points out, many of the methods employed have been expedient, although effective. In developing better methods, recourse has been taken to several chemical engineering techniques, which are described.

During the war emphasis was placed on the prime problem of producing fissionable material and converting it into a weapon. Treatment of wastes was postponed until the main job was accomplished. Postponement consisted of venting gases to the atmosphere through tall stacks, burying solids in wasteland areas, and holding liquid wastes in underground retention tanks. These temporary solutions worked well —so well in fact that there is considerable reluctance in some quarters to abandon any of them.

These three solutions represent three separate philosophies of waste disposal which might be called

1. **Dispersal**
2. **Controlled containment**
3. **Partially controlled containment.**

Disposal by dispersal relies on the adequacy of mixing of the waste with large volumes of water or air. Sufficient diluent must be available to bring the concentration of radioactivity below maximum permissible tolerances. Obviously venting of gases to the atmosphere falls into this class of disposal as does the discharge of liquid wastes into a large watercourse. As long as waste quantities remain small, this system has some merit. It certainly is the cheapest and easiest way. Limitations of the method will be discussed later.

At the opposite end of the philosophical scale is the theory that no activity should be released from the control of the producer. The bottling up of liquids in underground tanks is an attempt to use this method. Again as long as production is small, the method works well. But costs are high and there is the worry of tank rupture from natural or man-made cataclysms or from sheer deterioration of the tank. Between these extremes lies partially controlled containment in a place such that the escape rate is no longer controllable but is believed to be low. Burial of solids in trenches in the ground or the underground cribbing of liquid wastes leaves the activity subject to leaching by ground water, but sites can be selected where this effect is very slow.

The selection of one of these philosophies, or a combination of them, is an essential first step in determining just how the long-term waste problem is to be handled.

Radiation Characteristics of Wastes

The distribution of products born in fission is shown by the familiar saddle-shaped curve in Figure 1 *(3)*. Isotopes with mass numbers from 72 to 162 are formed with yields which vary from 6 to ~0.0001%.

During operation of a reactor, in each instant there is formed then a quantity of mixed fission product, the composition of which is indicated in Figure 1. However, each radioactive species has its own characteristic half life, and each varies from fractions of a second to greater than a million years. From the half life is calculated the decay constant, λ.

$$\lambda = \frac{0.693}{t_{\frac{1}{2}}} \qquad (1)$$

where $t_{\frac{1}{2}}$ = half life in convenient time units.

As soon as it is born, each fission product begins to decay according to its own particular decay constant. The accumulation of any particular fission product over a differential time element, dt, can be expressed by the equation

$$\frac{dn}{dt} = R - \lambda n \qquad (2)$$

where

n = weight of isotope
R = rate of production in weight/time (time units consistent with those used for λ in Equation (1).

The solution of Equation (2) is

$$n = \frac{R}{\lambda} + C_1 e^{-\lambda t} \qquad (3)$$

starting with $n = 0$ at $t = 0$

$$C_1 = -\frac{R}{\lambda} \qquad (4)$$

and Equation (3) becomes

$$n = \frac{R}{\lambda}\left[1 - e^{-\lambda t}\right]. \qquad (5)$$

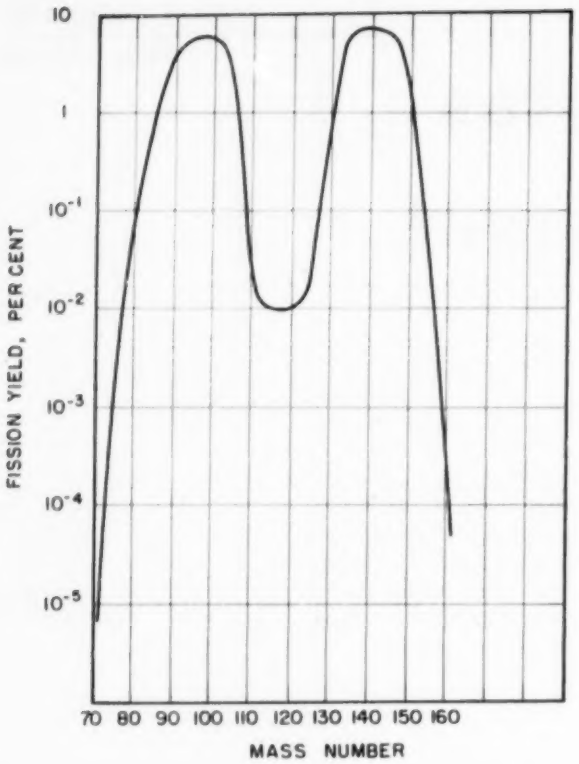

Fig. 1. (Left) Slow fission yields in U^{235}.

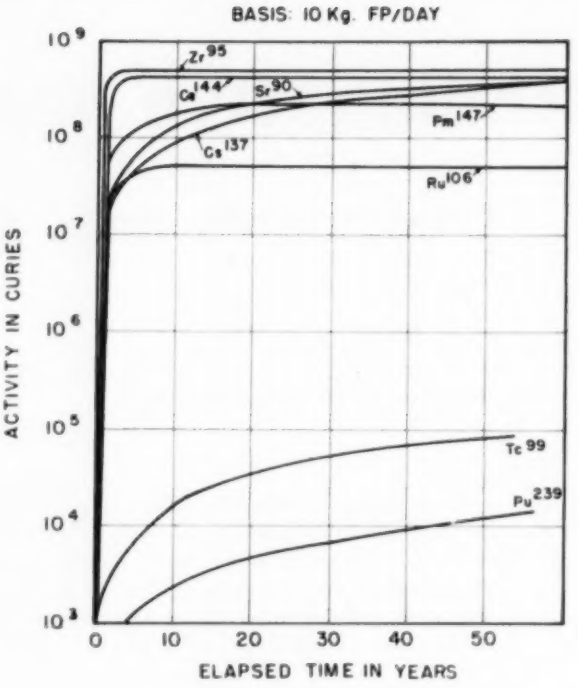

Fig. 2. (Above) Accumulation of long-lived fission products.

At $t = \infty$,

$$n = \frac{R}{\lambda}. \qquad (6)$$

This means that after a time which varies with the half life of the species, each fission product will approach a limiting concentration, R/λ. Those with short half lives reach this value very soon; those with long half lives take much longer.

Accumulation of Fission Products in Future

To illustrate the accumulation of fission products with time, figures are presented in Table 1 for eight of the most important long-lived isotopes, showing their accumulation over fifty years and their ultimate concentration, based on the assumption that 10 kg./day of total fission products are produced for the entire period. For reference, 10 kg./day of fission products would be produced by 9,000 megawatts (mw.) of installed reactor capacity. These results are plotted in Figure 2.

Estimates (*5, 10*) of the maximum plausible energy requirement supplied in the U. S. by nuclear energy in A.D. 2000 indicate that perhaps 750×10^6 kw. of installed reactor capacity may be in operation. This is equivalent to the production of one ton of fission products each day. Tripling this to 3 tons/day to allow for world rather than U.S. production, and if this production rate were maintained for fifty years, the accumulation of long-lived fission products that would result is shown in Table 2. Also, in Table 2, are shown the presently permissible tolerances for these isotopes, and from these are calculated the amounts of air and water which would be necessary to dilute the isotope in question to tolerance (*9*). (Note that Sr^{90} is the controlling isotope and that the dispersal volume of water needed, 2.6×10^7 cubic miles, is about 5% of the entire world ocean volume). Even ignoring the problems of inadequate mixing and reconcentration by marine life, it is clear that dispersal alone cannot be the long-term answer to the waste-storage problem. Even the oceans are not big enough to hold the activity which conceivably may be produced.

Waste Volume Accumulation

One is forced to turn, then, to some form of containment. Consider the magnitude of the problems involved herein using the same production estimate of 3 tons/day of fission products. Three tons of fission product per day is equivalent to processing 6,000 tons of natural uranium/day assuming a 7% "burn up" of the fissionable isotope, U^{235}. Some presently used processes produce in the order of 1,000 gal. of waste/ton of uranium processed. This means that six million gallons of waste would be produced each day—2×10^9 gal./year. Unprocessed—stored as received—this would mean an annual storage bill of two billion dollars a year. Though this is a staggering figure, this amount would still be only approximately 0.4 mil/kw.-hr. of electricity produced.

This volume can be reduced, of course, by selecting processes which initially produce a smaller waste volume, by using higher uranium enrichments or by several concentrating techniques. There will be, however, an irreducible volume which must be accepted. Taking as the most optimistic assumption that the inert salts can be held to a weight equal to the fission products themselves, 6 tons/day of concentrate will be formed. At a density of 100 lb./cu.ft. the volume formed is 120 cu.ft./day, 44,000 cu.ft./year. This is not an impractical number. Even if storage space for this volume cost \$50/cu.ft., the storage bill would be only \$2,000,000 a year. To this would have to be added, of course, the much larger cost of concentrating.

Table 1.—Accumulation of Long-Lived Fission Products

Basis: 10 kg. fission products/day ≅ 9000 megawatts installed reactor capacity

Isotope	Fission Yield %	Half Life	Decay Constant $\lambda = \frac{0.693}{t_{1/2}}$, sec.$^{-1}$	Ultimate Quantity Fission Product at equilibrium, Kg.	Curies	Accumulation of Fission Product Activity in Curies at time indicated: 10 y	20 y	30 y	40 y	50 y
Zr^{95}	6.4	65 d	1.23×10^{-7}	25	5.2×10^{5}	5.2×10^{5}	5.2×10^{5}	5.2×10^{5}	5.2×10^{5}	5.2×10^{5}
Ce^{144}	5.3	280 d	2.86×10^{-8}	133	4.3×10^{5}	4.3×10^{5}	4.3×10^{5}	4.3×10^{5}	4.3×10^{5}	4.3×10^{5}
Ru^{106}	0.5	1.0 y	2.2×10^{-8}	12	4.1×10^{7}	4.1×10^{7}	4.1×10^{7}	4.1×10^{7}	4.1×10^{7}	4.1×10^{7}
Pm^{147}	2.6	2.6 y	8.46×10^{-9}	225	2.1×10^{5}	1.9×10^{5}	2.1×10^{5}	2.1×10^{5}	2.1×10^{5}	2.1×10^{5}
Sr^{90}	5.3	19.9 y	1.1×10^{-9}	2150	4.3×10^{5}	1.3×10^{5}	2.2×10^{5}	2.8×10^{5}	3.2×10^{5}	3.5×10^{5}
Cs^{137}	6.2	33 y	6.65×10^{-10}	6350	5.0×10^{5}	9.5×10^{7}	1.7×10^{5}	2.3×10^{5}	2.8×10^{5}	3.3×10^{5}
Tc^{99}	6.2	2.1×10^{5} y	1.05×10^{-13}	2.9×10^{7}	5.0×10^{5}	16,500*	33,000	49,500	66,000	82,500
Pu^{239}	...	2.4×10^{4} y	.....	.....	.....	2,300**	4,600	6,900	9,200	11,500

* Decay neglected.

** Loss of 0.1% assumed on processing. Decay neglected.

Table 2.—50-Year Accumulation of Long-Lived Isotopes and Required Dispersal Areas

Basis: 2.2×10^{6} megawatt installed reactor capacity ≅ 3 tons fission products/day

Isotope	Accumulated Quantity in 50 y, curies	Maximum Permissible Concentrations in Water, μc/ml.	Maximum Permissible Concentrations in Air, μc/ml.	Volume Required to Dilute to Tolerance: Water, cubic miles	Volume Required to Dilute to Tolerance: Air, cubic miles
Zr^{95}	1.3×10^{11}	4×10^{-3}	4×10^{-7}	7.8×10^{9}	7.8×10^{7}
Ce^{144}	1.1×10^{11}	4×10^{-3}	7×10^{-9}	6.6×10^{9}	3.8×10^{9}
Ru^{106}	1.0×10^{11}	0.1	3×10^{-9}	2.4×10^{9}	8×10^{9}
Pm^{147}	5.1×10^{10}	1	2×10^{-7}	12	6×10^{7}
Sr^{90}	8.6×10^{10}	8×10^{-7}	2×10^{-10}	2.6×10^{7}	1×10^{11}
Cs^{137}	8.1×10^{10}	1.5×10^{-3}	2×10^{-7}	1.3×10^{4}	9.7×10^{7}
Tc^{99}	2.0×10^{7}	3×10^{-2}	3×10^{-6}	0.2	1.6×10^{3}
Pu^{239}	2.8×10^{6}	1.5×10^{-4}	2×10^{-12}	4.5×10^{2}	3.4×10^{5}

Bulk Reduction of Waste

If the premise is accepted that some long-term controlled containment will be necessary, it is obvious that an approach to the minimum bulk just calculated will be highly desirable.

Considerable information has been obtained on a number of concentrating techniques and much of this is reported in open as well as project literature (*6, 11*). Some pertinent data on evaporation, flocculation, ion exchange and electrodeionization are given in Table 3.

EVAPORATION

Evaporation has been the most widely used technique (*2, 8*). Several types of evaporators have been tried and all are satisfactory within limits. The concentration factor possible varies inversely with the solids content of the feed, but a broad range of feed solid content can be handled. Decontamination factors range from 10^{4} to 10^{6} for a single effect. Costs are high ranging from 5 to 10 cents/gal. processed.

FLOCCULATION

Variations of water-treatment practice have been studied exhaustively, and it appears that as a method for handling high level wastes, flocculation is not satisfactory (*4, 12*). With the use of a wide range of flocculating agents, overall decontamination factors of about 10 are obtained. Tailoring a process for a single species, better results can be obtained, but it is difficult to see how the technique can be applied to very active wastes. Advantages of the process are low cost (<$10/1,000 gal.), the ability to handle a wide range of solid content in the feed, and the production of a waste floc volume which is relatively independent of feed solid content.

ION EXCHANGE

Ion-exchange resins are quite useful within prescribed limits (*1*). Because the capacity of resin and the concentration factor obtainable vary inversely with the solid content of the feed, the method is of most interest for use on very low solid-content feeds. Cation resins will give decontamination factors of about 50, mixed beds of about 10^{5}. The cost is low (<$10/1,000 gal.) if the solid content of the feed is low enough.

ELECTRODEIONIZATION

An interesting alternative to ion exchange is the processes known as electrodeionization which makes use of permselective membranes and accomplishes a continuous regeneration of the membrane by the use of electric current rather than chemicals. The process has been applied to waste streams by Walters (*13*), and it is possible that better cost performance can be shown than that obtained from conventional resins.

Cost of Bulk Reduction and Storage

Possibly a useful combination might turn out to be an initial evaporative step followed by mixed-bed ion exchange. Such a process might be expected to give a volume reduction factor of 200 and a decontamination factor of 10^{10} and to cost about 10 cents/gal. of feed waste. Based on an earlier assumption of 2×10^{9} gal./year of waste produced, a cost estimate might be

Concentration	$200,000,000
Storage of 5×10^{5} cu.ft./year at $50	25,000,000
Total Yearly Cost	$225,000,000
Equivalent to	0.04 mil/kw.-hr.

Thus, while the $225,000,000 storage bill is high, the cost per kilowatt hour is in a range where the power economy probably could stand it. This estimate assumes no technological advances beyond what is known now.

There remains the $200,000,000/year incentive to find better ways to handle

Table 3.—Characteristics of Various Methods for Processing Radioactive Wastes

Process	Range of Solid Content in Feed	Variation of Concentration Factor with Solids	Decontamination Factor	Approx. Cost $/1,000 gal.
Evaporation	0–20%	Inverse	10^4–10^6	100
Flocculation	0–20%	Independent	10	10
Ion Exchange	0–0.3%	Inverse	30–10^5	10
Electrodeionization	0–0.8%	Inverse	100	10

this waste. Obviously processes which produce a highly concentrated waste—perhaps approaching the minimum bulk already calculated—are most desirable from this standpoint. Several such processes are under consideration.

Fission Product Utilization

Much has been written about the possibility of using fission-product wastes for industrial purposes. In a discussion of waste disposal, it should be pointed out that the problem of final disposal is not changed in any way by the use (or lack of it) of the products for a period of time during their early life. Two advantages can be gained by industrial utilization, however:

1. Concentration of the waste to minimum bulk and high specific activity is of necessity accomplished, thus reducing the final storage bulk (and cost).
2. Part or all of the cost of waste handling can be paid for by the use of the radiation. If one could find a market for all of this radiation at a price of $20 a megacurie, the income would be greater than $250,000,000/year or enough to pay for the storage bill. Surveys have indicated that industry might be willing to pay more than this sum for activity, but no recognizable market for $>10^{10}$ curies/day exists as of now. (For that matter neither does the 10^{10} curies.)

At the present time, most of the experimentation on fission-product utilization is being done with cobalt sources. A single mixed fission-product source (containing about a kilocurie of year-old activity) has been prepared at Argonne National Laboratory. This source is being used at Massachusetts Institute of Technology. A description of its preparation will be published (*7*).

Sources made from reactor fuel elements which simulate a mixed waste source rather well are available at the National Reactor Testing Station in Idaho and soon will be available at Argonne National Laboratory.

Final Storage of Wastes

If in the next several decades anything like the quantity of fission product which has been hypothesized is actually produced, it is clear that this generation has a serious responsibility to future generations in deciding just what will be the final disposal. Many suggestions have been made. Some are listed herein and some personal opinions are expressed.

1. STORE AS CONCENTRATED LIQUIDS

Storing as concentrated liquids would have to be done in buried concrete or metal tanks. If the liquids were concentrated enough, the cost and space allocation might not be much higher than for solids storage. However, it is difficult to imagine such a tank farm in which no serious leakage could occur during 200 years (10 Sr^{90} half lives) due to corrosion, calamity or combat.

The industrial use of the wastes is essentially impossible. For the long term this solution appears impractical.

2. IMMOBILIZE AS SOLIDS

If alternative (1) is rejected, then immobilizing as solids obviously must be done. Several methods have been demonstrated on batch or pilot plant scale. None has yet been adequately proved out for the long term.

Wastes have been concentrated to the point where they solidify on cooling and the solids stored in drums. The reliability of the method depends on drum sealing and corrosion of the drum metal. Again, it is difficult to conceive of no leakage for more than 200 years, and the solids certainly are highly leachable.

Concentrated wastes have had Portland cement added so that they set to a mortar. The wastes are thus immobilized at a volume increase cost of two. While the activity is thus made much less mobile, still no "nonleachable" cement has ever been produced.

Much more promising are the suggestions for adsorbing the wastes on clays or on glass- or ceramic-forming substances and then vitrifying them. It should be possible to find a method such that reasonable volumes are formed of a product which is essentially unleachable.

Of even more controversy is the decision as to what to do with the storable solid once made. Suggestions here have included dropping in ocean deeps and storage in desert areas or abandoned mines. The non-leachability of the prepared solid would have to be exhaustively proved before one could afford to commit these quantities of radiation to the ocean deeps. Even then we would be losing final control of tremendous quantities of radioactivity. It is the opinion of the author that, at least for the present generation, a plan should be made to maintain control of the waste in deserts or mines. In any event, the decision should be given careful and competent thought on an international level.

Acknowledgment

The author wishes to express his appreciation to S. Lawroski, I. G. Dillon, and P. Fineman for their counsel and assistance in the preparation of this paper.

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Opinions and speculations contained herein are those of the author except where otherwise credited. They do not reflect official policy of either Argonne National Laboratory or A.E.C.

This paper describes the restoration program necessitated by an accident which occurred at the Chalk River project when its reactor released into the building and equipment thousands of curies of fission products. Some details of the original accident will be given along with an explanation of the problems and techniques. Generally, it is hoped to demonstrate that severe pile accidents need not result in hazards to personnel, either associated with the equipment or located in the surrounding district; also that such accidents need not result in complete loss of the plant, but that, through the various steps of reconstruction and decontamination, the reactor can be returned to normal operation.

Decontamination of the Canadian Reactor

F. W. Gilbert Atomic Energy of Canada Limited, Chalk River, (Ont.), Canada

A power surge occurred in the Canadian nuclear reactor on Dec. 12, 1952. This surge was sufficient to cause failure to the aluminum sheaths of about 10% of the uranium rods. Both melting and oxidation of the uranium accompanied this failure. As a result approximately 10,000 curies of radioactive fission products were carried below the pile in the cooling water, and, at the same time, fission products were spread throughout the reactor structure and into the ancillary equipment.

From Figure 1 which represents the Chalk River reactor (NRX), the extent of the contamination problem can be seen. The basement contained considerable equipment including many instruments. It is provided with a sump and pump, but the water, in this case, was too highly radioactive to send to the normal disposal. The basement had to be used as a reservoir until other provisions could be made.

Briefly the situation after the accident happened was as follows:

1. The reactor vessel was damaged beyond repair.
2. It contained highly irradiated uranium which could not be removed in the normal way.
3. Practically all the ancillary equipment was contaminated.
4. The basement area was flooded with water which left a residual contamination in the concrete of 10 r./hr. on the average.
5. The ceiling, walls, and floor of the upper part of the building were contaminated to approximately 50 mr./hr.
6. Local "hot" spots were as high as 3,000 r./hr.

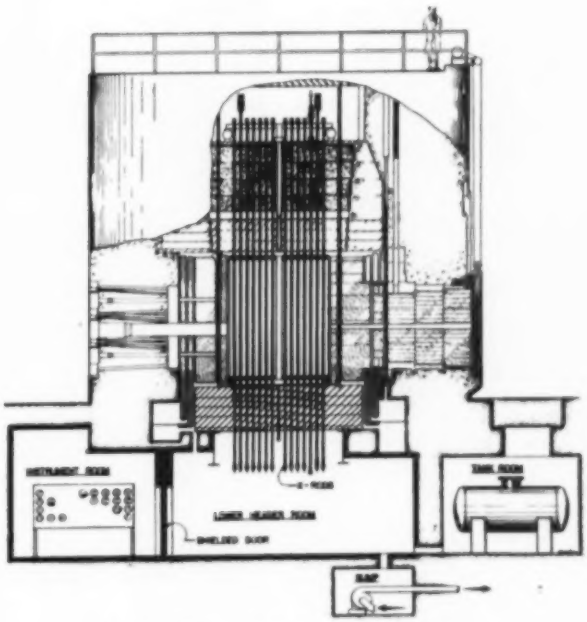


Fig. 1. Diagram of Chalk River reactor (NRX).

All the radiation figures are approximate.

The repair of equipment after such an accident is merely one of economy. In reactor repair, economy refers directly to the safety of the men employed on the job.

By Feb. 1, 1954, the reactor was completely reassembled and the activity levels in working areas of the building

were lower than they had been before the accident. This was accomplished with only one person receiving more than 15 r. in the 14-month period. This particular man received about 17 r. Although some ingested activity was encountered, no individual case was considered serious by the medical officer. No case with a detectable residual activity remains. And, in addition, not a single lost-time injury was suffered.

On the economic side, it would have cost about four times as much to replace the reactor and would have taken nearly three times as long. Certainly repair in this case has proved to be the correct solution.

The experience at Chalk River has indicated that generally the life of a reactor need be limited only by its usefulness. If this principle is accepted, then construction should be such that all parts of a reactor are readily removable for replacement or cleaning. A small effort made in this regard would have greatly reduced the effort and time of repair of the NRX pile.

The first major problem faced after the accident took place was the disposal of 1,000,000 gal. of water containing some 10,000 curies of radioactivity. This problem was first solved by using a process water reservoir for storage. In the meantime, a 1¼-mile pipe line was installed to a disposal area. The active water was pumped through this line to open pits and allowed to seep through the soil which very effectively removed the activity (Figure 2). If provision had been made before the accident for this water disposal, the basement contamination would have been greatly reduced. Also the decontamination of the water reservoir would have been avoided. This pipe line also served as an excellent method of transporting active material to the disposal area in later cleaning.

The next problem was to prove the feasibility of removing the reactor vessel and its damaged rods. As the most direct way to prove this was to try it, the next stage in the operation was to dismantle the reactor.

In the middle of this operation one of the most serious problems was encountered—ingestion of radioactive material. The medical officer wisely set a very low permissible level for ingestion. For some reason that could not be related directly to the air contamination, a number of men exceeded the permissible dosage and had to be removed from contaminated areas for a period of time. This problem was solved by the following procedures:

1. By improving the ventilation. This was done by installing ducts so that the flow of air came from the areas of lowest activity to the highest and then out through the filter-house. An additional circulating fan with filters was installed.
2. By improving the hygiene of the men.
3. By continuous vacuum cleaning and mopping of all working areas.
4. By closer control of respirators—the major corrective factor. Originally only the filter medium of the respirators was checked before issuing. The reliability of the source was considered sufficient for the other characteristics. This proved to be definitely misplaced confidence. All types of respirators

Fig. 2. Pipe line for active water disposal.

Fig. 3. Decontamination operator.

Fig. 4. Decontamination operator. Showing variation in suit and mask.

in use were shown to have faults. The present practice is to inspect every respirator before it is issued and after each decontamination. In addition to this, each respirator is called in from the field periodically for testing.

Respirators were used in levels of activity up to 7 times tolerance. Above this level masks and hoods having supplied air were used. Self-contained air-supply units were not used because of the difficulty of decontaminating the equipment and the number required.

Some of the clothing used is shown in Figures 3, 4, 5 and 6.

The extent of the air contamination problem can be grasped when one realizes than 1 mc. is more than sufficient activity to contaminate a 100-ft. cube above tolerance level.

After a preliminary period of trial and error a general pattern of decontamination was followed. The steps in the procedure were

1. The area was flushed with water—the water being pumped to the disposal area.
2. A high velocity stream of hot water with and without detergents was used for a second flushing. (Before detergents are used their effect on the water disposal should be known.)
3. All possible equipment was removed. Wherever possible the equipment was wrapped before being sent to decontamination or disposal areas. (See Figure 7.)
4. A third flushing followed.
5. A survey was made for local "hot" spots. These were cleaned or shielded.

Fig. 5. Decontamination operator. Further variation in mask.

Fig. 6. Decontamination operator. More fully protective gear.

At this stage, unless there was induced activity present, the activity level would be down to about 5 to 10 r-units/hr. for the "hottest" areas.

One useful device for finding local hot spots was the pinhole camera. This is shown in Figures 8 and 9. In action it took two pictures, one by light and one by gamma ray. By superimposing the two negatives high-activity spots were quickly localized over quite large areas. This is demonstrated in Figure 9.

The cleaning of these "hot" spots required a variety of techniques. When the "hot" spots were on the floor, it was sometimes possible to flood the area with a couple of feet of water for shielding. After the removal of gross activity, final cleaning was done by a number of methods.

Concrete was decontaminated by removing the surface by flame priming, chipping, sand-blasting, and grinding. Where grinding and sand-blasting were used the equipment was connected to a vacuum system to remove the dust. Failure of one of these vacuum systems produced an air activity of 1,500 times tolerance. Finally, in most cases where

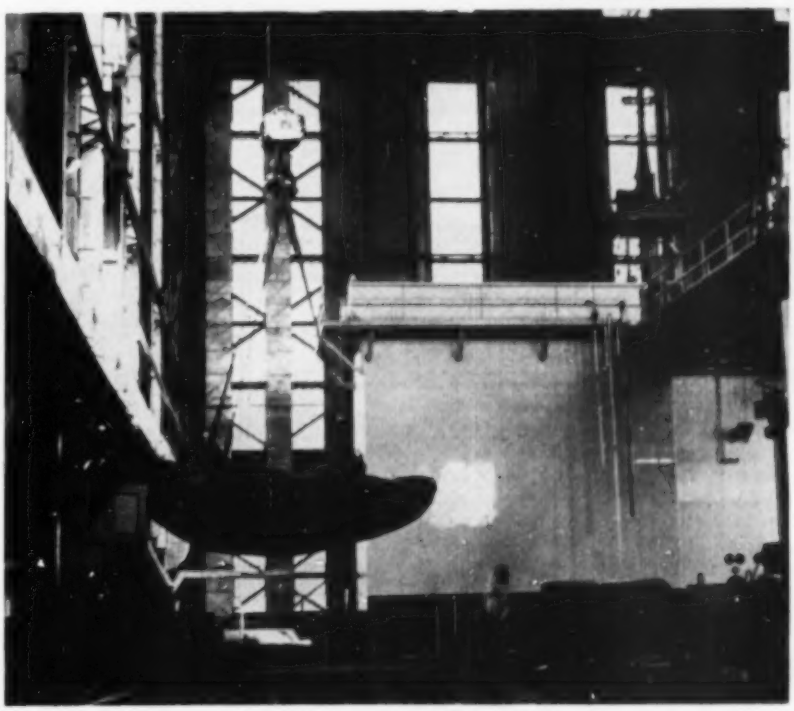


Fig. 7. Removal of contaminated shield.

the concrete had been contaminated with active water, it was necessary to seal in the remaining activity and pour concrete over this as a shield. This was not done until the level was reduced to about 20 mr./hr. on contact.

Lead can be most easily decontaminated by removing, melting, and recasting. The active material rises to the surface of the melt and can be skimmed off.

Other surfaces were cleaned by scrubbing. Stainless steel responded best to a transfer technique. In this method the surface is scrubbed with cotton wipers which are changed frequently. The activity is transferred from the steel to the wipers. This method worked much better than scrubbing with brushes and flushing. Detergents or acids were used with the wipers. Recently consideration has been given to the use of such materials as bentonite for this purpose, but up to the present no experimenting has been done with them.

Mild steel responded fairly well to scrubbing with brushes and detergents. If rust was present, inhibited hydrochloric acid was used.

As soon as a surface was cleaned, it was protected from recontamination by a covering with paper.

The decontamination program required the help of many persons not acquainted with the building or equipment. Models, mock-ups, and photographs were valuable for giving instructions. On-the-job instruction unnecessarily uses the exposure time of men and supervisors. Because experienced supervisors were scarce, their exposure time was hoarded carefully.

In re-assembly the following measures have been taken to reduce the difficulties in the event another accident should occur

1. Permanent active water disposal is being provided.
2. Wherever possible, equipment has been removed from the basement.

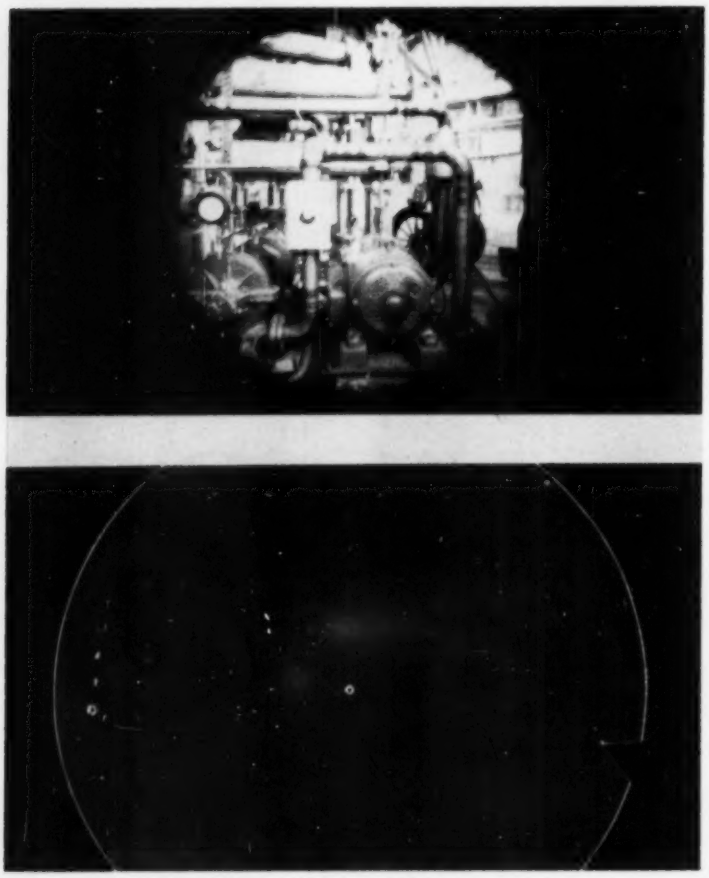
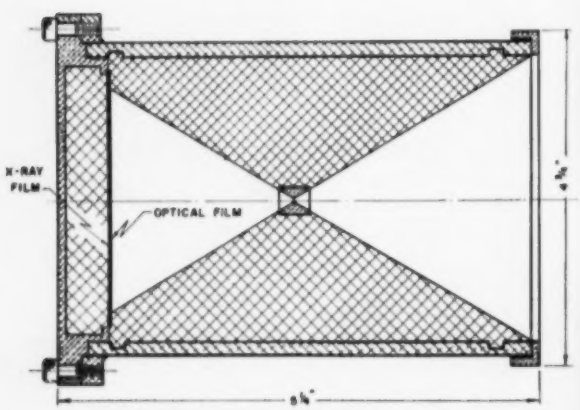


Fig. 9. Photographs taken with pinhole camera.



▲ Fig. 8. Cross section of pinhole camera.

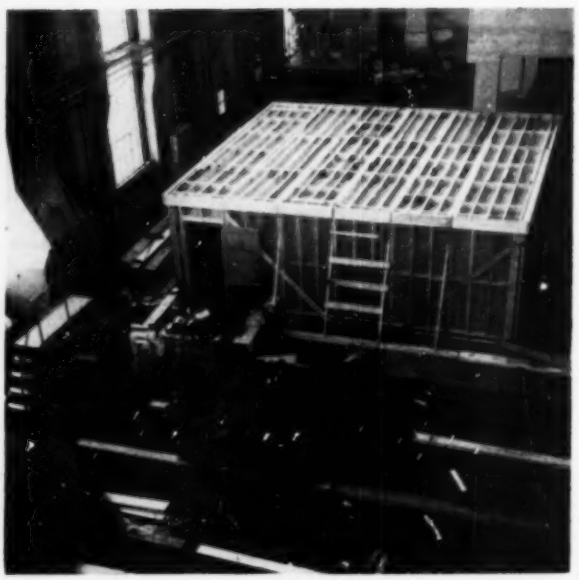


Fig. 10. A temporary, separately ventilated structure used for decontaminating large pieces of equipment. ►

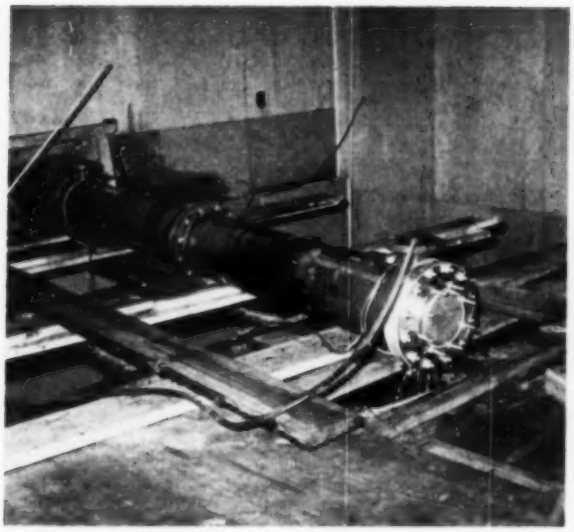


Fig. 11. A heat exchanger inside decontamination room.

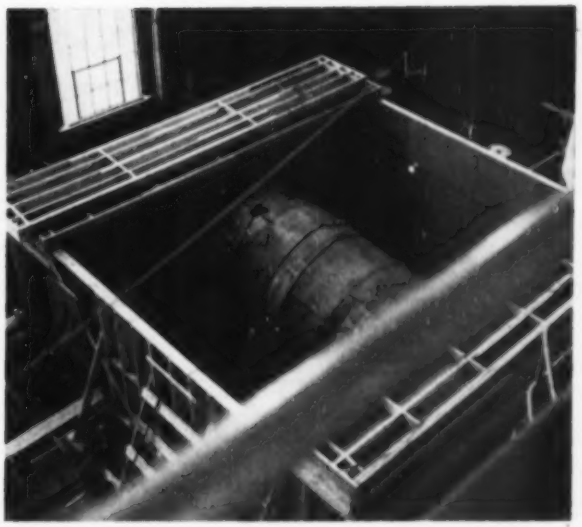


Fig. 12. Another view of the decontamination room, showing how the roof could be removed for installation of large pieces of equipment.

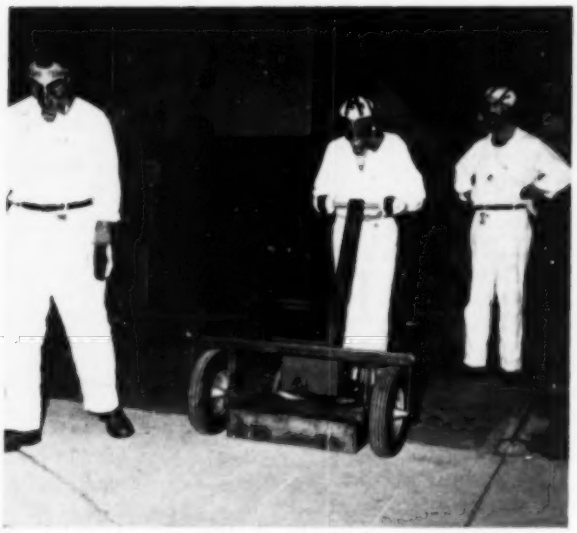


Fig. 13. A specially constructed survey instrument for checking the activity on the floors.

Fig. 14. All cracks in the concrete had to be chipped out. This figure shows the operation.

3. All surfaces likely to be contaminated are being painted or otherwise sealed. These include even lead and stainless steel. Rubber tile is being used for the main floor.
4. All cracks and crevices are being filled and sealed.

These measures do not seem too extensive, but had they been taken before instead of after the accident, much labor would have been saved.

Obviously the best way to cope with a contaminated reactor is to prevent its happening. The next best is to take measures to reduce the damage. Fortunately these measures are not excessively expensive and are also an aid to normal pile operation.

Acknowledgment

Acknowledgment is here expressed to Henry Hurwitz, Jr., of Knolls Atomic Power Laboratory for pinhole camera technique, to the Naval Radiological Defense Laboratory for general advice and assistance, and to U.S.A.E.C. and Canadian Armed Services for supplying manpower.

Figure at the head of this article shows a floor grinder used for removing a contaminated surface of the concrete.

ALUMINUM ALLOY REFERENCE SHEET

HARRY W. FRITTS — Aluminum Company of America, New Kensington, Pa.

Cast Alloys 43, B214, and 356

Commercial Products:

43—Sand, permanent mold, and die castings

B214—Sand casting

356—Sand and permanent mold castings.

Applications and Remarks: These alloys are used for fittings, valve and pump bodies, manholes, and in general the various castings that might appear on or in connection with aluminum process equipment and piping. Alloys 43 and 356 both are excellent general-purpose casting alloys. They have excellent casting characteristics and pressure tightness, good weldability and good resistance to corrosion. Alloy B214 is somewhat more difficult to cast, has greater strength than 43, and excellent resistance to corrosion. High mechanical properties can be developed in 356 by heat-treating.

A.S.T.M. Designations:

43—S5A (sand and PM) S5C (die)

B214—GS42A (sand)

356—S670A (sand and PM)

A.S.T.M. Specifications:

B26, B108 (sand and PM) B85 (die)

B26 (sand)

B26, B108 (sand and PM)

ALUMINUM ALLOY

MECHANICAL PROPERTIES:

	Alloy—As Cast			
	43 (sand)	43 (PM)	43 (die)	B214 (sand)
Tensile strength, lb./sq.in.	19,000	23,000	30,000	20,000
Yield strength, lb./sq.in.	8,000	9,000	16,000	13,000
Elongation—% in 2 in.	8	10	9	2
Shear strength, lb./sq.in.	14,000	16,000	19,000	17,000
Brinell hardness—500 kg load, 10 mm ball	40	45	—	50

	Alloy 356				
	Sand			Permanent Mold	
	—T51	—T6	—T7	—T6	—T7
Tensile strength, lb./sq.in.	25,000	33,000	34,000	40,000	33,000
Yield strength, lb./sq.in.	20,000	24,000	30,000	27,000	24,000
Elongation—% in 2 in.	2.0	3.5	2.0	5	5
Shear strength, psi.	20,000	26,000	24,000	32,000	25,000
Brinell hardness—500 kg. load, 10 mm ball	60	70	75	90	70

PHYSICAL PROPERTIES:

	43 (S & PM)	43 (die)	B214 (S)	356 (S & PM)
Modulus of elasticity, lb./sq.in.	10,300,000	10,300,000	10,300,000	10,400,000
Specific gravity	2.69	2.65	2.65	2.68
Weight—lb./cu.in.	0.097	0.096	0.096	0.097
Melting range, °F.	1065°-1170°	1060°-1170°	1090°-1170°	1035°-1135°
Thermal conductivity— B.t.u./(hr.)(sq.ft.)(° F./in.)	1016—as cast 1132—annealed	987	1016	1161 (—T51) 1045 (—T6) 1074 (—T7)
Average coefficient of thermal expansion— in./° F. x 10^{-6}				
68°—212°	12.3	12.3	12.7	11.9
68°—392°	12.9	12.9	13.3	12.7
68°—572°	13.4	13.4	13.8	13.0
Electrical conductivity— % of International Annealed Copper Standard	37—as cast 42—annealed	37	38	43 (—T51) 39 (—T6) 40 (—T7)

Composition:

43—5% Si, bal. Al

B214—1.8% Si, 3.8% Mg, bal. Al

356—7.0% Si, 0.3% Mg, bal Al

Machinability: All three alloys can be satisfactorily machined at relatively high machine speeds. Sharp tools and a high rake angle are necessary. Alloy 356 has the best machining characteristics, followed by B214 and 43.

Heat Treatment: Alloys 43 and B214 are nonheat-treatable casting alloys. Castings from these alloys come in "as cast" condition. Alloy 356 is heat-treatable. Alloy 356 sand castings are available in —T51 or as cast and artificially aged, in the —T6 or solution heat-treated and artificially aged, and the —T7 or solution heat-treated and stabilized condition. Alloy 356 permanent mold castings normally are made in the —T6 and —T7 tempers.

Weldability: Can be satisfactorily welded by most of the common welding methods using alloy 435 wire. Alloys 43 and 356; good welding characteristics. Alloy B214 slightly more difficult to weld. Inert gas shielded welding methods often preferred to minimize distortion and/or flux contamination.

CORROSION RESISTANCE

ACIDS

Acetic, all concs., r.t.*	E
Acetic, other than glacial, boiling	P
Acetic glacial, anhydride, boiling, r.t.*	E[1]
Benzoic, sat. soln., boiling	E
Boric, 7% soln, 180° F.*	E
Butyric, all concs., r.t.*	E
Butyric anhydride, r.t.*	E
Carbolic (phenol), all concs., to 240° F.*	E
Carbonic, all concs., r.t.*	E
Chromic, below 10%, r.t.	G
Cresylic (Cresol), r.t.	E
Fatty, up to boiling*	E[1]
Hydrochloric, all concs.	N
Hydrocyanic, all concs., r.t.*	E
Hydrofluoric, anhydrous, 200° F.*	E
Hydrofluoric solutions	N
Lactic, anhydrous, r.t.*	E
Lactic, up to 10%, r.t.*	E
Maleic, 30%, r.t.	E
Maleic anhydride, molten *	E
Malic, to 50%, r.t.	E
Naphthenic, up to 180° F.*	E[1]
Nitric, above 82%, to 120° F.*	E
Nitric, below 82%, r.t.	P
Nitric, red fuming, up to 120° F.*	E
Oleic, up to boiling *	E[1]
Oxalic, all concs., r.t.*	G
Oxalic, all concs., elevated temperature	P
Phosphoric, all concs.	N
Phthalic, molten	E
Phthalic anhydride, molten *	E
Propionic, all concs., r.t.*	E
Propionic anhydride, r.t.*	E
Stearic, up to boiling *	E[1]
Sulfuric, fuming	G
Sulfuric, other than fuming	N
Sulfurous, r.t.	F
Tannic, all concs., pure, r.t.	E
Tartaric, all concs., r.t.*	E

ALKALIES

Ammonium hydroxide, comm'l., r.t.*	E
Calcium hydroxide, all concs.	P
Potassium hydroxide, all concs.	N
Sodium hydroxide, all concs.	N

ALKALINE SALTS

Potassium carbonate, all concs.	P
Sodium bicarbonate, r.t.	E
Sodium carbonate, all concs.	P
Sodium sulfide	P

NEUTRAL SALTS

Calcium chloride, all concs., to 200° F.	G[+2]
Calcium sulfate, sat. soln., r.t.*	G+
Calcium sulfide, all concs., r.t.*	G
Magnesium chloride, all concs r.t.	G+
Magnesium sulfate, to 50% soln., r.t.	G
Potassium chloride, all concs., r.t.	G+[2]
Potassium nitrate, all concs., r.t.	E
Potassium sulfate, all concs., r.t.	E
Sodium chloride, all concs., r.t.*	G+[2]
Sodium nitrate, all concs., r.t.*	E
Sodium sulfate, all concs., r.t.*	E

ACID SALTS

Alum,, paper makers, r.t.*	E
Aluminum chloride, dry, 70° F.	G
Aluminum chloride, moist	P
Aluminum sulfate, r.t.*	E
Ammonium chloride, all concs., r.t.*	G+
Ammonium nitrate, all concs., to 285° F.*	E
Ammonium sulfate, all concs., r.t.*	E
Copper chloride, nitrate, sulfate	P+
Ferric chloride, nitrate, sulfate	P+
Lead chloride, nitrate, sulfate	P+
Mercury salts	N+
Nickel chloride, nitrate, sulfate	P+
Silver salts	P+
Stannous and stannic salts	P+
Zinc chloride	P+

GASES

Acetylene, dry *	E
Air, wet or dry, hot or cold *	E
Ammonia, dry *	E
Bromine	N
Carbon dioxide, wet or dry, hot or cold *	E
Chlorine, wet or elevated temps.	N
Freons *	E
Hydrogen sulfide, wet or dry, hot or cold *	E
Nitrogen, wet or dry, hot or cold *	E
Oxygen, wet or dry, hot or cold *	E
Sulfur dioxide, dry	E
Sulfur dioxide, wet	F

ORGANIC MATERIALS

Acetone, r.t.*	E
Alcohols, pure, r.t.*	E
Aniline, all concs., to 212° F.	G
Benzaldehyde, r.t.*	E
Benzene, to boiling *	E
Carbon disulfide, to boiling *	E
Carbon tetrachloride, dry, r.t.*	E
Chloroform, dry, r.t.	E
Ethyl acetate, pure, r.t.	E
Formaldehyde *	G+
Furfural, r.t.*	E
Gasoline, to boiling *	E
Glycerine, to boiling *	E
Glycols, ethylene and propylene, r.t.*	E
Mercaptans, amyl, r.t.*	E
Methyl ethyl ketone *	E
Oils, crude, essential, refined, vegetable *	E
Oils, sour crude (H_2S)*	E
Trichloroethylene, dry, r.t.*	E

PICKLING OPERATIONS

Acetic acid (Mag. Products)*	E
Sulfuric plus dichromate	N
Sulfuric plus hydrochloric	N

FOOD INDUSTRY

Brines, inhibited *	E
Edible oils and fats *	E
Fatty acids *	E
Fruits and fruit juices *	G
Vegetables *	G
Milk products *	E
Beer *	E

PAPER MILL APPLICATIONS

Kraft	N
Black, Green liquor	N
White liquor	F
Sulfite liquor	P
Chloride bleach solution	P
Chloride bleach vapors	G
Hydrogen peroxide (above 30%)*	E
Paper makers alum *	E
Humid and chemical atmospheres *	E

PHOTOGRAPHIC INDUSTRY

Humid atmospheres *	E
Cellulose acetate *	E
Acetic anhydride *	E
Developers	P
Silver nitrate	P+
SO_2 solutions	P

FERTILIZER INDUSTRY

Ammonia, anhydrous *	E
Ammoniated ammonium nitrate *	E
Urea *	E

* Aluminum alloys used commercially.

\+ Subject to pitting-type corrosion.

[1] Must have trace of moisture present at boiling temperature.

[2] May be inhibited with sodium chromate.

RATINGS:

E—Excellent resistance. 0.00½ max. in./year of penetration. Corrosion so slight as to be harmless.

G—Good resistance. 0.00½-0.01⅝ in./year of penetration. Satisfactory service expected; at most a slight etch.

F—Fair resistance. 0.01⅝-0.120 in. of penetration/year. Satisfactory service under specific conditions. Light to moderate attack.

P—Poor resistance. 0.120-0.320 in. of penetration/year. Satisfactory for temporary service only.

N—Aluminum not recommended. Rate of attack high.

r.t.—Room temperature.

No. 33

The Development of Nuclear Power

Four new reactors, designed to answer many of the problems standing in the way of economical power from the atom, are announced in the accompanying paper, a condensation of an address delivered at the Washington, D. C. national meeting of A.I.Ch.E.

Henry D. Smyth Member, U. S. Atomic Energy Commission

The structure of modern industrial society depends on plentiful supplies of energy. There is never enough. New sources are always being sought. Yet the most generous sources of energy that nature has supplied—the winds, the tides, the rays of the sun, are untapped. How to harness these great natural forces has not yet been learned.

Fifteen years ago a new natural force was discovered, the fission of uranium. Now the country is engaged in an effort to harness this atomic energy for peaceful purposes. It is a great effort and indeed should be so, for success in it may materially change the lives of men. The road to success will be a long one. It will have many dead ends and wrong turnings and many dull and dreary stretches. The barriers to be surmounted or by-passed are formidable.

By now one knows what these barriers are, what kinds of problems have to be solved if nuclear power is to be significant in our economy. The people should know these problems, for it is now fifteen years since nuclear fission was discovered, ten years since the first large-scale nuclear reactor was started, and five years since the Atomic Energy Commission announced its first program of nuclear reactors aimed at power. Energy from nuclear power plants will be just like energy from coal-burning power plants. Except for special purposes, the sole criterion of comparison will be cost.

General Problems of a Nuclear Power Reactor

The three major facts of nuclear fission are: first, that enormous amounts of energy are released; second, that the products of fission are radioactive; and third, that fission is caused by neutrons and results in the production of further neutrons, thereby making a chain reaction possible.

These basic facts confront the designers of reactors with a series of technical questions which can be grouped in the following five general areas.

NEUTRON ECONOMY

Four things can happen to the neutrons that are produced in the fission process. *First*, since neutrons are extremely penetrating, they may simply escape to the outside environment. One obvious way to reduce this possibility (escape of neutrons) is to increase the amount of uranium present. The more uranium there is, the more likely neutrons will be absorbed in it and cause fission rather than escape.

A second way in which they disappear is by capture by U^{238} without causing fission. The second possibility can be minimized by using a slowing-down material, a moderator, and arranging the uranium in a lattice. Another way is to eliminate part or all of the U^{238} isotope since it contributes very little to the fission process and does absorb many neutrons.

Third, they may be captured by impurities in the uranium, by structural materials, or coolants. The third possibility requires that the uranium itself be highly purified in the first place and that structural materials be used which have a low capacity for the absorption of neutrons. This last consideration puts many restrictions in the path of the designer of a nuclear chain reactor.

Fourth, they may be captured by U^{235} resulting in fission. If the fourth process produces more neutrons than are lost by the first three processes, the chain reaction occurs.

EFFECTS OF NUCLEAR RADIATION

Effects of nuclear radiation have several aspects that the designer needs to keep in mind. Perhaps the most important one technically is the fact that the constant bombardment of structural materials and of uranium itself causes changes in their properties. The result may be a change of shape, embrittlement, change in thermal conductivity, or of almost any other property. The rate of corrosion of a material is likewise affected.

Nuclear radiation is dangerous to health. Consequently, the whole reactor structure must be surrounded by a shield which will not be penetrated by radiation. This is present not only while the reactor is running, but induces a lasting radioactivity in the materials of the reactor. When fuel elements are unloaded for chemical processing, they have to be handled by remote control. Similarly, maintenance must be held to an absolute minimum, and actual direct access to the heart of the reactor must be avoided.

HEAT TRANSFER OR REMOVAL

The designers of a power reactor must extract the energy in a form which can be put to use. The problems involved differ from those of ordinary heat transfer for the following reasons: The choice of materials is limited by neutron economy, corrosion effects may be enhanced by the radiation present, and the replacement of parts is difficult or impossible because of the health dangers involved.

CONTROL

By now, enough experience has been gained so that a reactor can be controlled. In fact, some types of reactor are self-controlling. There remain, however, problems of convenience, efficiency, and cost.

CHEMICAL PROCESSING OF FUEL

The growth of fission products and of the corrosion or radiation damage of structural materials or fuel elements makes it impossible to consume more than a fraction of a nuclear charge in any known design of reactor. After a certain length of time it is necessary to remove the fuel. It is too valuable to throw away, containing some 90 per cent or more fissionable material. Consequently, it is necessary to reprocess chemically to separate out the fission products, and refabricate the uranium into new forms. This turns out to be one of the most costly processes in the whole business of operating a reactor for power.

It is the author's opinion that the nuclear power industry will stand or fall economically depending on the success which chemists and chemical engineers have in developing cheap processes for purifying and refabricating nuclear fuel.

Breeding

U^{235} is the isotope of uranium in which fission occurs most readily. Unfortunately, it is present in natural uranium only one part to 140. Natural uranium is none too plentiful, and to be able to use only seven tenths of a per cent of it is frustrating. Neutrons, absorbed in the other uranium isotope, U^{238}, lead to the production of plutonium, which is readily fissionable. The operation may be so regulated that the plutonium is produced in greater quantity than the U^{235} "burned" up. Such a process is called a "breeding."

This is, of course, a fascinating idea. It turns out, however, that it may not be

so important whether the amount of plutonium produced is slightly less or slightly greater than the amount of U^{235} "burned" up. A reactor that produces plutonium in smaller quantity than uranium "burned" is a converter and one where the quantity produced is greater than that of uranium "burned" a *breeder*. In either case, it should be possible eventually to convert the fission energy of both isotopes of uranium to useful power. In the case of the converter, there would be some reactor loss; in the case of the breeder, these losses would be zero. In either case, the losses in chemical processing would make the difference not very significant. The difference, however, between using just U^{235} and eventually using all of the uranium in natural uranium is enormous and may well make the difference between an ample supply of nuclear fuel for many years to come and a rather scanty one.

The First A.E.C. Reactor Program

When the Atomic Energy Commission took over the plant and equipment of the Manhattan District in January, 1947, the problems that have been reviewed were already clear. Early in 1949, the first program was announced as consisting of a plan to build four major reactors. Three of these have been finished at the Idaho Test Site and are described here.

The first was the materials testing reactor, MTR. It has, for two years, been used to get information on the effects of radiation on uranium fuel elements or other materials that might be used as tubes for cooling water, or as coolants, or containers for uranium fuel elements.

The second reactor built at Idaho was the experimental breeder reactor, EBR. It has demonstrated that breeding is possible.

The third reactor was a special-purpose one aimed at providing power for a submarine thermal reactor, STR.

In all three of these reactors, the neutron-economy problem was solved by using uranium from which much of the U^{238} isotope had been extracted. This does not seem to be the system which will be built for power purposes.

The fourth undertaking initiated later was the homogeneous reactor experiment at Oak Ridge. The homogeneous reactor uses a solution of uranyl sulfate in water. The water serves as the moderator, and the uranyl sulfate molecules serve as the fuel elements in which the chain reaction is set up.

The immediate and obvious advantage of the homogeneous reactor is that fuel fabrication and processing are enormously simplified. The solution is pumped continuously through the reactor chamber and then cooled in outside heat exchangers, and some of it recycled for purification, then re-introduced into the circulating stream of combined fuel and moderator. The homogeneous reactor is self-regulating. As the temperature of the reactor rises, its reactivity decreases and therefore it controls itself. One difficulty experienced was that the water was dissociated by the radiation, but, it was found that the hydrogen and oxygen formed could be recombined without too great difficulty.

One of the most interesting experiments that has been done was carried out last summer at the Idaho Test Site by Dr. Zinn, director, by building a small reactor with the deliberate intention of finding out about what would happen to a water-cooled reactor if the flow of water should be cut off. When it was set up, it had an arrangement in it which suddenly ejected the control rods so that the power generated by the chain reaction went up in a fraction of a second from a few watts to many thousands of watts. This caused the water to boil so violently that it was ejected from the reactor in a small geyser. Repeated trials showed that in every case the boiling reduced the power of the reactor so rapidly that no serious damage was done.

Results of Past Five Years, Present Status of Art

Some of the major results obtained in the last five years are summarized here.

As to neutron economy, a great deal has been learned about the probabilities of various nuclear events, including the relationship between the probability of fission and the energy of the neutrons. It was found that a number of different substances can be used as moderators, specifically beryllium, light water, and heavy water in addition to the familiar graphite.

As to the effects of radiation on materials, the MTR has been of greatest value. Benefits have resulted from studying the fuel elements in the EBR and in the STR. A great variety of alloys has been made and various fuel elements have been tested. STR has shown that fuel elements, sheathed in zirconium, will resist corrosion and radiation effects over considerable periods of time and represent a great improvement over the aluminum sheathed fuel elements in the Hanford reactors. Radiation effects have also been studied in a variety of coolants, including sodium and heavy water.

In the matter of heat transfer, heat can be removed from a reactor by circulating molten sodium-potassium alloy, pure sodium or pressurized water.

As to control and instrumentation it has already been found that certain types of reactors are self-regulating as a result of boiling or near-boiling as the temperature rises. Hafnium is now used as a material for control rods, as it is such an excellent absorber of neutrons.

In the matter of chemical processing, experience has been gained with actual processing of the various types of fuel elements in the new reactors. We have proved that the homogeneous reactor will work, and, therefore we know that that is one direction in which to hope for improvement.

In the matter of costs, none of the reactors that have actually been put up is cheap, either to build or to operate. The STR probably costs somewhere around $2,000/kw. to build; a modern steam plant costs $180/kw. But the STR does prove one over-all major result—that it is possible to build a reactor for the production of power that will run for at least reasonably long times continuously and efficiently.

Questions Still to Be Answered

The *fundamental question* still to be answered is whether a power-producing uranium reactor can be built which will compete with other sources of energy. The homogeneous reactor does simplify chemical processing, but it requires enriched fuel and it is not yet certain that the corrosion problems can be solved. The breeder has not yet been proved on any large scale; hence, it is not known how expensive that may be. The STR uses expensive materials for cladding the fuel elements, is almost certainly not competitive. It also uses enriched material. And so it goes all through the list.

Proposed Five-Year Program

There are six programs that should be pursued. One of these is the general program of research on fundamental properties of materials, on nuclear reactions, on components that might go into the reactors of the future and on chemical processes. This work will be continued principally in Argonne and Oak Ridge laboratories. In addition the desire is to build five reactors of varying size and cost. The Commission has recently submitted to the Joint Committee on Atomic Energy a special report on the reactor program prepared at the request of the Committee.

The *first* of these reactors is in the new program has already been publicly announced. It is the so-called PWR, pressurized water reactor, rated at 60,000 kw. of electric power. It will use slightly enriched uranium as fuel, ordinary water as a moderator and coolant. The water in the reactor, it is assured, will be under 2,000 lb./sq.in. p. and at a temperature between 500 and 600° F. Steam will be delivered to the turbine at about 600 lb./sq.in. The temperature is limited by the corrosion of the fuel elements and piping and container, and the pressure is limited by the

(*Continued on page 50*)

Preview

Ann Arbor Meeting

First International

Nuclear Engineering Congress

Ann Arbor, Michigan—June 20-25, 1954

Sponsored jointly by the Nuclear Engineering Division of the A.I.Ch.E. and the University of Michigan—to bring together chemical engineers and the world's great nuclear scientists for five-plus days of technical sessions and social events, with liberal opportunities and facilities for informal discussion and recreation.

In late June when many will be looking forward to vacation travel, the University of Michigan, located at the southern terminus of one of the most popular summer-recreational areas in the central Midwest, will be host to chemical engineers from all parts of the country. This meeting with the world's outstanding nuclear scientists and engineers, the men who have been doing the major share of the development of peacetime uses of atomic energy, will take place in an atmosphere of friendly informality and will provide an outstanding program of papers revealing the latest of techniques and fundamentals. Host for the meeting will be the Detroit Section of A.I.Ch.E. Dr. R. R. White, professor, chem. eng., Univ. of Michigan, will be general chairman.

Michigan as Vacationland

Michigan offers many vacation and resort facilities comparable with any area of the U. S. The slogan "Water Wonderland" is on all Michigan automobile licenses this year as an indication of the multitude of inland lakes, plus the Great Lakes bordering the state on nearly all three sides. In the western part, Michigan is renowned as a fruit-growing region. In the eastern section around Detroit, it is heavily industrialized. In the north, scenic attractions abound, as do the fish in the many lakes and streams. In late June and early July, Upper Michigan is the mecca of many Midwesterners seeking relief from the heat. In Traverse City, in the northern section, the famous National Music Camp at Interlochen will open June 27. In early July, special events take place in Presque Isle County, Frankfort, Saugatuck, Alpena, Gladstone, Lake City, and Jackson, to mention a few. A postcard to the Michigan Tourist Council, Lansing, will bring full information about the state's many attractions.

Outstanding Meeting Planned

The Congress has been in preparation for more than one year, and has received the cooperation of the U. S. Atomic Energy Commission as well as several foreign governments. Dr. Donald L. Katz of the university, as chairman of both the Nuclear Engineering Division of the Institute, and of the technical program committee of the Congress, has secured an outstanding

Some of those coming from near and far to make the Congress possible.

Left to right: H. Hatcher, Pres., U. of Mich. (U.S.); G. Randers, Dir., Jt. Estab. for Nucl. Energy Res. (Norway); W. S. Cole, Chmn., Jt. Atomic Energy Comm. (U.S.); J. Van Impe, Consultant, Centre D'Etudes L'Energie Nucleaire (Belgium); W. H. Zinn, Dir., Argonne Nat'l Lab. (U.S.); J. M. W. Milatz, Netherlands Reactor Commissaris; D. L. Katz, Chmn., Div. of Nuclear Eng., A.I.Ch.E. (U.S.); H. A. B. Bryneilsson, Pres. Aktibologet Atomenergi (Sweden).

variety and quality of program material.

Whether or not previously interested in nuclear developments, chemical engineers engaged in all phases of industrial and institutional activities will find this meeting of great interest and value. Nuclear engineering is of broad potential application, ranging from the use of minute quantities of radioactive materials for liquid level measurement to the large systems for production of steam to be used for generation of electric power. It is expected that this Congress, the activities of the Nuclear Engineering Division, and the issuance of the published material by C.E.P. will materially aid and abet the adoption by chemical engineers of certain nuclear techniques on one hand, and on the other hand, the integration of even more chemical engineers into purely nuclear system development work.

Spacious Facilities

The location of the meeting in Ann Arbor is particularly fortunate from many standpoints. Facilities of the university are spacious and provide not only meeting and discussion places but also ample housing so that all will be adequately and pleasantly taken care of. The Hill Auditorium, for example, seats 4,200, a suitable locale for the day-long "Social Impact Program." Other meetings will be held in the Rackham Building, seating 1,150, and the Natural Science Building, seating 500. Housing will be in the Michigan Union and South Quadrangle. The latter was completed in 1952, and has a capacity of 1,200. The Union contains spacious social, conference, dining, cafeteria, and hotel-type facilities. In addition, there are bowling alleys, a swimming pool, and a billiard room. The university offers wide recreational opportunities for men and women—golf, swimming, tennis—and its museum. Various laboratories and buildings will be open for inspection.

General Program

The meeting will get underway at 2:00 p.m. Sunday afternoon, June 20, with a symposium on the employer's viewpoint as to training desirable for nuclear engineers. At this D. W. McLenegan of G. E., P. N. Powers of Monsanto, and R. Witzke of Westinghouse will represent industry, and a comparable panel will represent educational institutions, in the lecture hall of the Rackham Building. At 5:00 p.m. the schedule calls for a supper and carillon concert in Michigan League. At 8:00 p.m. a duo-piano concert in Angell Hall will provide a fitting setting for what may in retrospect be the entrance of the chemical engineer into the rudimentary nuclear world, which he is expected to help perfect.

Daily luncheons in the Union will be addressed by prominent speakers. On Monday the luncheon speaker will be Morse Salisbury, director, Division of Information Services, U. S. Atomic Energy Commission.

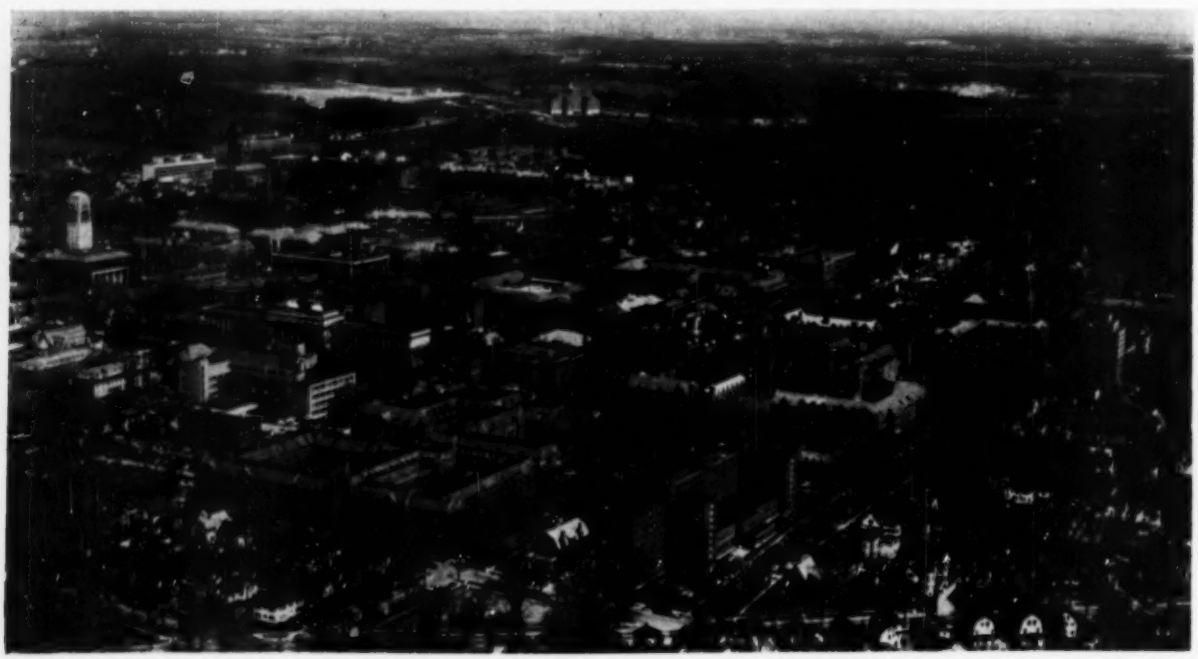
Tuesday's luncheon will be called an "international luncheon" as foreign guests will be introduced by Alberto Thompson, director, Technical Information Services, U. S. Atomic Energy Commission. Luncheon guests will hear an address by A. M. Weinberg, director of research, Oak Ridge National Laboratory.

A dinner to be held Tuesday evening will be addressed by Carroll A. Hochwalt, vice-president, Monsanto Chemical Co.

Wednesday will be a busy day socially, with L. J. Hayworth, director, Brookhaven National Laboratory, as a luncheon speaker. Then in the early evening a President's reception will introduce guests to both the president of A.I.Ch.E., C. E. Kirkbride, and the president of the university, Dr. Harlan Hatcher. Later in the evening a joint meeting with the Mass Communications Conference group (in concurrent meeting) will be held.

On Thursday, Hon. W. Sterling Cole, chairman, Joint Committee on Atomic Energy, U. S. Congress, will be the luncheon speaker. For the banquet Thursday evening a speaker of international importance will appear. Unfor-

Aerial view of University of Michigan campus. The tall building in the immediate foreground is South Quadrangle, chief housing center for the Congress.

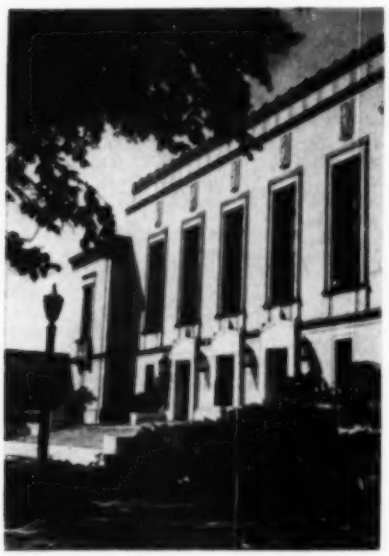


tunately it is not possible to announce the identity of the speaker at press time.

Ladies' Program

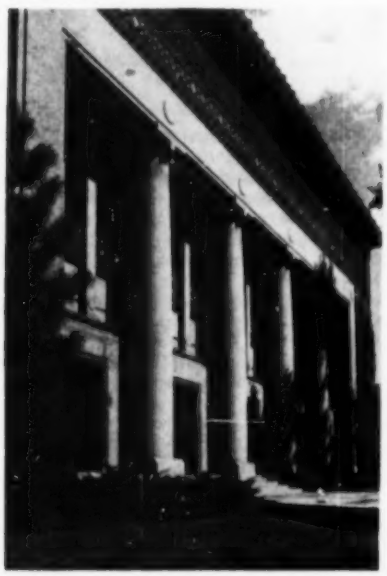
An entertaining ladies' program has been arranged under the guidance of Mrs. Donald L. Katz, chairman. In addition to the group entertainment functions to be shared with the men, a coffee hour and a tour of the campus have been scheduled for Monday. On Tuesday a tour of Detroit or one of the food service and out-patient clinics of the university is offered, followed by a luncheon and an afternoon tour of suburban Detroit's famed Cranbrook Institute of Science and Art Museum.

A tour on Wednesday includes historical Greenfield Village and luncheon at Dearborn Inn, and a visit to Edison Village promises an atmosphere of carefully preserved early American lore.



Most of the daily sessions of the congress will be held in the Rackham Building.

Hill Auditorium will be the center for Thursday's day-long program on the Social Impact of Atomic Energy.



Technical Program

Throughout the week simultaneous sessions will be held in the different locations. A brief description of these is as follows:

RESEARCH AND EDUCATIONAL REACTORS. (Monday a.m. and Tuesday a.m.)

This session deals with the reactors that have been designed, built, and operated specifically for research studies, which have called for features, controls and accessories intended to effect the widest degree of flexibility of operation.

MATERIALS OF REACTOR CONSTRUCTION. (Monday a.m. and p.m.)

The materials used in reactors, even the fuels themselves, are subjected to extreme conditions of corrosion and change in physical properties due to neutron bombardment, plus the other radiation effects. Coping with these phenomena is a necessary part of the over-all problem of achieving successful nuclear power.

REACTOR TECHNOLOGY—HEAT TRANSFER AND FLUID FLOW. (Tuesday a.m.)

These operations are employed in withdrawing heat from the reactor and are both complicated through corrosion and intense radioactivity. At the present state, economic levels of temperature and fundamentals are being compared for the various types of reactors.

REACTOR FUEL REFINING AND PREPARATION. (Tuesday a.m. and p.m.)

Beginning with the ores and ending with metals, a series of chemical engineering steps has made possible the large-scale production of hitherto "rare" metals.

REACTOR TECHNOLOGY—REACTOR STATICS AND KINETICS. (Tuesday p.m.)

Fundamentals of phenomena and the design considerations related to different types of reactors are covered.

REACTOR TECHNOLOGY—APPLICATION OF MATERIALS TO REACTOR SYSTEMS. (Wednesday a.m.)

The practical aspects of materials choice to meet certain functional needs are discussed.

SEPARATIONS TECHNOLOGY—PROCESSING OF IRRADIATED MATERIALS. (Wednesday a.m. and p.m.)

Spent fuels must be "cleaned" to remove neutron-absorbing (chain reaction interfering) impurities. Wastes must be treated to concentrate highly radioactive components to simplify the disposal problem. Compounds employing "tagged" atoms must be prepared. To accomplish these and other tasks, a new technique of "remoteness," special isotope separation operations, and other techniques have been evolved.

REACTOR TECHNOLOGY—DESIGN AND OPERATING PROBLEMS. (Wednesday p.m.)

Selected subjects exemplify the kinds of problems dealt with by the designer and operator.

SOCIAL IMPACT OF NUCLEAR ENERGY. (Thursday a.m. and p.m.)

This non-technical session will provide many thought-provoking considerations which may offer as much need for solution as do the more obvious technico-economic problems.

APPLICATION AND USES OF RADIOACTIVE PRODUCTS. (Thursday p.m. and Friday a.m.)

Nuclear energy can be used to initiate chemical reactions and perform a number of other useful functions, some of which are described.

AUTOMATIC COMPUTATION IN NUCLEAR ENGINEERING. (Friday p.m.)

Some of the problems in the design and control of nuclear reactors are particularly benefited by solution-techniques employing automatic computation techniques.

International Conference on Mass Communications, June 19-23

Under the joint sponsorship of the School of Journalism of the University of Michigan and the A.I.Ch.E., and taking place concurrently with the Congress, this conference will attract scientific writers, editors, and program directors. Under the direction of Professor Wesley H. Maurer, the discussions will deal with problems facing the world press in the area of atomic information brought on by censorship, secrecy, and the difficulty of transmitting complex ideas to the public. The program will consist of two parts; one, a briefing on the broader technical aspects of nuclear energy by qualified members of the University of Michigan "Phoenix Project"—the code name for the nuclear energy research and development program, and two, discussion of the problems of reporting.

Interested journalists are invited to contact Professor Maurer.

Exposition

An Atoms-for-Peace Exposition will be held in conjunction with the Congress. Instruments, models, and other educational exhibits will be in the galleries of Rackham Building, many by industrial firms. Copies of Nuclear Engineering—Part I, a volume in the C.E.P. Symposium Series, will be on sale at a nominal price. Everyone attending the Congress is cordially invited to visit the Exposition and discuss his interests with the qualified representatives who will be present.

TECHNICAL PROGRAM

Ann Arbor Meeting

Monday, June 21, A.M.

TECHNICAL SESSION No. 1

(Simultaneous with Session No. 2)

Research and Educational Reactors I

Chairmen—L. M. K. Boelter and F. Perrin

THE NRL RESEARCH REACTOR: DESIGN AND RESEARCH PROGRAM, E. H. Krause, Naval Research Laboratory, Washington, D. C.

THE OPERATIONAL CHARACTERISTICS OF A HEAVY-WATER REACTOR, A. Lundby, Joint Establishment for Nuclear Energy Research, Kjeller, Norway.

RESEARCH REACTOR PROGRAM AT THE PENNSYLVANIA STATE COLLEGE, W. M. Breazeale, The Pennsylvania State College, State College.

SAFETY CONSIDERATIONS IN THE SELECTION OF UNIVERSITY RESEARCH REACTOR DESIGNS AND LOCATIONS, L. C. Widdoes, University of Michigan, Ann Arbor, Mich.

A DESCRIPTION OF THE ARGONNE NATIONAL LABORATORY RESEARCH REACTOR, CP-5, J. T. Weills, Argonne National Laboratory, Lemont, Ill.

THE SWEDISH REACTOR, S. Eklund, The Atomic Energy Co., Stockholm, Sweden.

NUCLEAR REACTORS FOR RESEARCH, (Motion Picture.) H. Pearlman, North American Aviation, Inc., Downey, Calif.

TECHNICAL SESSION No. 2

(Simultaneous with Session No. 1)

Materials of Reactor Construction I

Chairmen—M. C. Leverett and K. H. Kingdon

THE TECHNOLOGY AND FABRICATION OF GRAPHITE, L. D. Loch and J. A. Slyh, Battelle Memorial Institute, Columbus, Ohio.

MEASUREMENT OF THE DIFFUSION LENGTH OF THERMAL NEUTRONS IN GRAPHITE, J. G. Fite, Junda de Energia Nuclear, Madrid, Spain.

PREPARATION, PROPERTIES, AND USES OF BERYLLIUM, E. J. Boyle and J. L. Gregg, Oak Ridge National Laboratory, Oak Ridge, Tenn.

MELTING AND FABRICATION OF ZIRCONIUM, J. W. Holladay and J. G. Kura, Battelle Memorial Institute, Columbus, Ohio.

POWDER METALLURGY OF ZIRCONIUM AND BERYLLIUM, H. H. Hausner and H. B. Michaelson, Sylvania Electric Products, Inc., Bayside, N. Y.

CORROSION OF ZIRCONIUM IN HIGH TEMPERATURE WATER, D. E. Thomas, Westinghouse Electric Corp., Pittsburgh, Pa.

STUDIES IN THE URANIUM-BISMUTH FUEL SYSTEM, D. H. Gurinsky and J. E. Atherton, Brookhaven National Laboratory, Upton, N. Y.

Monday, June 21, P.M.

TECHNICAL SESSION No. 3

(Simultaneous with Session No. 4)

Materials of Reactor Construction II

Chairmen—W. B. Lewis and C. Starr

CORROSION AND IMPURITIES IN THE HEAVY-WATER SYSTEM OF THE DUTCH-NORWEGIAN REACTOR, T. J. Barendregt and K. H. Brakstad, Joint Establishment for Nuclear Energy Research, Kjeller, Norway.

PROCESSES FOR THE PRODUCTION OF HEAVY WATER, P. J. Selak and J. Finke, United States Atomic Energy Commission, Savannah River Operations Office, Augusta, Ga.

A THERMAL METHOD FOR CONCENTRATING HEAVY WATER, E. Cerrai, C. Marchetti, R. Renzoni, L. Roseo, M. Silvestri, S. Villani, Laboratori, C.I.S.E., Milano, Italy.

RADIATION DAMAGE TO WATER, A. O. Allen, Brookhaven National Laboratory, Upton, N. Y.

RADIATION DAMAGE TO NON-METALLIC MATERIALS, V. P. Calkins, General Electric Co., Cincinnati, Ohio.

RADIATION EFFECTS ON STRUCTURAL MATERIALS, C. R. Sutton and D. O. Leeser, Argonne National Laboratory, Lamont, Ill.

TECHNICAL SESSION No. 4

(Simultaneous with Session No. 3)

Research and Educational Reactors II

Chairmen—J. A. Lane and T. C. Johnson

A HIGH PERFORMANCE RESEARCH REACTOR, J. P. Gill, Oak Ridge National Laboratory, Oak Ridge, Tenn.

TEN YEARS OPERATING EXPERIENCE WITH ORNL GRAPHITE MODERATED NORMAL URANIUM REACTOR, M. E. Ramsey and C. D. Cagle, Oak Ridge National Laboratory, Oak Ridge, Tenn.

THE COOLING SYSTEM OF THE SACLAY PILE, M. Goldschmidt, France. (Presented by F. Perrin, Commissariat a l'Energie Atomique, Paris.)

A NUCLEAR REACTOR FOR METALLURGICAL RESEARCH, J. J. O'Conner and L. S. Foster, Watertown Arsenal, Watertown, Mass.

THE FAILURE AND DISASSEMBLY OF THE LOS ALAMOS FAST REACTOR, E. T. Jurney, Los Alamos Scientific Laboratory, Los Alamos, N. M.

THE HARWELL FAST REACTOR (ZEPHYR), J. V. Dunworth, Atomic Energy Research Establishment, Harwell, England.

Tuesday, June 22, A.M.

TECHNICAL SESSION No. 5

(Simultaneous with Session No. 6)

Reactor Technology I—Heat Transfer and Fluid Flow

Chairmen—T. B. Drew and D. L. Katz

FORCED-CONVECTION HEAT TRANSFER IN PIPES WITH VOLUME-HEAT-SOURCES WITHIN THE FLUIDS, H. F. Poppendiek, Oak Ridge National Laboratory, Oak Ridge, Tenn.

HEAT TRANSFER TO SUPERCRITICAL WATER AND OTHER FLUIDS WITH TEMPERATURE-DEPENDENT PROPERTIES, K. Goldmann, Nuclear Development Associates, Inc., White Plains, N. Y.

PRESSURE DROP AND HEAT TRANSFER TO NON-BOILING AND BOILING WATER IN TURBULENT FLOW IN AN INTERNALLY HEATED ANNULUS, R. Stein, J. Hoopes, M. Markels, W. A. Selke, A. J. Bendler, C. F. Bonilla, Columbia University, New York, N. Y.

HEAT EXCHANGE IN LIQUID-METAL-FUEL REACTOR FOR POWER, O. E. Dwyer, Brookhaven National Laboratory, Upton, N. Y.

THE TEMPERATURE DISTRIBUTION IN A NUCLEAR REACTOR PIERCED BY CIRCULAR COOLING CHANNELS, P. B. Richards, Babcock and Wilcox Co., Alliance, Ohio.

USE OF THE CYCLIC HEAT-TEMPERATURE VARIATION METHOD FOR MEASUREMENT OF REACTOR HEAT-TRANSFER COEFFICIENTS, S. L. Fawcett and R. E. Grimble, Battelle Memorial Institute, Columbus, Ohio.

TECHNICAL SESSION No. 6

(Simultaneous with Session No. 5)

Reactor Fuel Refining and Preparation I

Chairmen—J. W. Clegg and J. Van Impe

THE EXTRACTIVE METALLURGY OF URANIUM, R. D. Macdonald, Battelle Memorial Institute, Columbus, Ohio.

METALLURGY OF URANIUM, H. A. Saller and F. A. Rough, Battelle Memorial Institute, Columbus, Ohio.

THORIUM METALLURGY, J. R. Keeler, Battelle Memorial Institute, Columbus, Ohio.

ELECTROLYTIC PREPARATION OF URANIUM FROM FLUORIDE BATH, S. K. Kantan, N. Shreenivasan, and G. S. Tendolkar, Tata Institute of Fundamental Research, Bombay, India

THE AMES PROCESS FOR SEPARATION OF MONAZITE, M. Smutz, G. L. Bridger, K. G. Shaw, and M. E. Whatley, Ames Laboratory, Atomic Energy Commission, Iowa State College, Ames, Iowa.

Tuesday, June 22, P.M.

TECHNICAL SESSION No. 7

(Simultaneous with Session No. 8)

Reactor Fuel Refining and Preparation II

Chairmen—G. H. Clewett and G. S. Tendolkar

PROCESS FOR RECOVERING THORIUM AND RARE EARTHS FROM MONAZITE, A. E. Bearse, G. D. Calkins, J. W. Clegg, and R. B. Filbert, Jr., Battelle Memorial Institute, Columbus, Ohio.

CAUSTIC TREATMENT OF ZIRCON SAND, G. H. Beyer, D. R. Spink, J. B. West, and H. A. Wilhelm, Iowa State College, Ames, Iowa.

A PROCESS FOR RECOVERY OF URANIUM FROM PITCHBLENDE DIGESTION RESIDUES, G. E. Brown and C. W. Kuhlman, Jr., Mallinckrodt Chemical Works, St. Louis, Mo.

PREPARATION AND FABRICATION OF PURE METALLIC URANIUM, J. Van Impe and C. Decroly, Centre d'Etudes pour les Applications de l'Energie Nucleaire, Brussels, Belgium.

TECHNICAL SESSION No. 8

(Simultaneous with Session No. 7)

Reactor Technology II—Reactor Statics and Kinetics

Chairmen—M. C. Edlund and H. Brynielsson

THE ROLE OF EXPONENTIAL EXPERIMENTS IN REACTOR DESIGN, E. R. Cohen, North American Aviation, Inc., Downey, Calif.

APPROXIMATIONS OF THE KINETIC BEHAVIOR OF FAST REACTORS, R. A. Fayram, Univ. of California, Berkeley, and K. Bernstein, Univ. of California, Los Angeles.

NON-UNIFORM FUEL DISTRIBUTIONS IN NUCLEAR REACTORS, G. Goertzel and W. A. Loeb, Nuclear Development Associates, Inc., White Plains, N. Y.

REACTOR DYNAMICS OF THE LOS ALAMOS WATER BOILER, P. R. Kasten, Oak Ridge National Laboratory, Oak Ridge, Tenn.

CALCULATION OF THE CHARACTERISTIC FACTORS OF A URANIUM-GRAPHITE LATTICE, R. Ortiz Fornaguera, A. Carbo and T. Iglesias, Junta de Energia Nuclear, Madrid, Spain.

APPLICATION OF ANALOG COMPUTER TECHNIQUES TO REACTOR DYNAMIC ANALYSIS, J. C. Moise, Pratt and Whitney Aircraft, East Hartford, Conn.

APPLICATION OF ANALOG COMPUTING TECHNIQUES TO THE SOLUTION OF NEUTRON FLUX DISTRIBUTION PROBLEMS, H. C. Honeck and D. G. Ott, Pratt and Whitney Aircraft, East Hartford, Conn.

Wednesday, June 23, A.M.

TECHNICAL SESSION No. 9
(Simultaneous with Session No. 10)

Reactor Technology III

Application of Materials in Reactor Systems

Chairmen—S. McLain and J. M. W. Milatz

ENGINEERING PROBLEMS PERTINENT TO THE USE OF NaOH IN REACTORS, E. M. Simons, Battelle Memorial Institute, Columbus, Ohio.

A COMPARATIVE EVALUATION OF SOME COOLANTS FOR POWER REACTORS, T. T. Shimazaki, North American Aviation Co., Downey, Calif.

LIQUID METAL FUELS AND LIQUID METAL BREEDER BLANKETS, R. J. Teitel, J. S. Bryner, and D. H. Gurinsky, Brookhaven National Laboratory, Upton, N. Y.

LIQUID FUEL REACTORS WITH URANIUM OXIDES, J. J. Went and N. V. Kema, Arnhem, Netherlands, and H. de Bruyn, Staatsmijnen in Limburg, Netherlands. (Members, Netherlands Reactor Committee.)

EXPERIENCE WITH GRAPHITE AS A FABRICATION MATERIAL IN HIGH TEMPERATURE HEAT TRANSFER SYSTEMS, R. D. Keen, North American Aviation, Inc., Downey, Calif.

MATERIALS TESTING REACTOR — STRUCTURE TEMPERATURES, G. H. Hanson, A. V. Grimaud, and K. A. McCollom, Phillips Petroleum Co., Idaho Falls, Idaho.

TECHNICAL SESSION No. 10
(Simultaneous with Session No. 9)

Separations Technology I

Processing of Irradiated Materials

Chairmen—S. Lawroski and A. S. White

THE DEVELOPMENT OF RADIOCHEMICAL PROCESSES, C. M. Nicholls and A. S. White, Atomic Energy Research Establishment, Harwell, England.

THE PROCESSING OF LIQUID BISMUTH ALLOYS BY FUSED SALTS, D. W. Bareis, R. H. Wiswall, Jr., and W. E. Winsche, Brookhaven National Laboratory, Upton, N. Y.

THE SYSTEM URANYL NITRATE-DIETHYL ETHER-WATER EXTRACTION BY WATER IN SPRAY AND PACKED COLUMNS FROM URANYL NITRATE-ETHER SOLUTIONS, L. G. Jodra, A. P. Luina, and A. Oroz, Junta de Energia Nuclear, Madrid, Spain.

PULSE COLUMN VARIABLES, G. Sege and F. W. Woodfield, Hanford Atomic Products Operation, Richland, Wash.

THE DESIGN PHILOSOPHY OF REMOTE OPERATION AND MAINTENANCE OF SEPARATIONS FACILITIES, W. M. Harty, Hanford Atomic Products Operation, G. E. Co., Richland, Wash.

PROCESSES FOR HIGH-LEVEL WASTE DISPOSAL, B. Manowitz and L. Hatch, Brookhaven National Laboratory, Upton, N. Y.

Wednesday, June 23, P.M.

TECHNICAL SESSION No. 11
(Simultaneous with Session No. 12)

Separations Technology II

Processing of Irradiated Materials

Chairmen—F. L. Culler and A. S. White

TREATMENT, USE, AND ULTIMATE DISPOSAL OF RADIOACTIVE WASTES, W. A. Rodger, Argonne National Laboratory, Lemont, Ill.

RECENT DEVELOPMENTS IN PULSE COLUMN TECHNIQUES, J. D. Thornton, Atomic Energy Research Establishment, Harwell, England.

A LOUVER-PLATE REDISTRIBUTOR FOR LARGE-DIAMETER PULSE COLUMNS, F. W. Woodfield and G. Sege, Hanford Atomic Products Operation, G. E. Co., Richland, Wash.

LIQUID METAL FUEL REACTOR PROCESSING LOOPS, C. Raseman and J. Weisman, Brookhaven National Laboratory, Upton, N. Y.

A CONTINUOUSLY SEPARATING BREEDER BLANKET USING THORIUM FLUORIDE, F. T. Miles, R. H. Wiswall, R. J. Heus, and L. P. Hatch, Brookhaven National Laboratory, Upton, N. Y.

TECHNICAL SESSION No. 12
(Simultaneous with Session No. 11)

Reactor Technology IV

Design and Operating Problems

Chairmen—J. R. Huffman and J. J. Martin

SELECTION OF OPTIMUM TEMPERATURE CONDITIONS IN POWER REACTORS AND THEIR HEAT EXCHANGER SYSTEMS, C. H. Robbins, North American Aviation, Inc., Downey, Calif.

RECOMBINATION OF RADIOLYTIC GAS FROM AQUEOUS NUCLEAR REACTORS, H. M. Busey and R. P. Hammond, Los Alamos Scientific Laboratory, Los Alamos, N. M.

PROBLEMS OF RADIATION AND CONTAMINATION IN THE RESTORATION OF THE NRX REACTOR, F. W. Gilbert, Atomic Energy of Canada, Ltd., Chalk River, Ont., Canada.

HIGH TEMPERATURE CENTRIFUGAL PUMPS, H. W. Savage and W. G. Cobb, Oak Ridge National Laboratory, Oak Ridge, Tenn.

GENERAL PURPOSE OVERHEAD MANIPULATOR, G. H. Sittner, General Engineering Laboratory, General Electric Co., Schenectady, N. Y.

Thursday, June 24, A.M.

TECHNICAL SESSION No. 13
(Simultaneous with Session No. 14)

Nuclear Power Reactors I

Chairmen—G. Randers and L. C. Widdoes

PRINCIPLES OF HEAT REMOVAL FROM NUCLEAR REACTORS, W. A. Loeb, Nuclear Development Associates, White Plains, N. Y.

PROBLEMS OF POWER REACTOR DESIGN, W. E. Abbott, North American Aviation, Inc., Atomic Energy Research Department, Downey, Calif.

THE EXPERIMENTAL BREEDER REACTOR, H. V. Lichtenberger, Argonne National Laboratory, Chicago, Ill.

THE HOMOGENEOUS REACTOR EXPERIMENT, S. E. Beall and C. E. Winters, Oak Ridge National Laboratory, Oak Ridge, Tenn.

A PILOT PLANT FOR NUCLEAR POWER, THE SGR, W. E. Parkins, North American Aviation, Inc., Atomic Energy Research Department, Downey, Calif.

NON-TECHNICAL SESSION, No. 14
(Simultaneous with Session No. 13)

Social Impact of Nuclear Energy I

Chairman—B. F. Dodge

THE IMPACT OF NUCLEAR ENERGY ON SAFETY AND THE CITIZEN, Robert J. Hansen, Department of Civil and Sanitary Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

THE IMPACT OF NUCLEAR ENERGY ON HEALTH, Shields Warren, Cancer Research Institute, Deaconess Hospital, Boston, Mass.

THE IMPACT OF NUCLEAR ENERGY ON INDIVIDUALS, Stephen Withey, Institute for Social Research, University of Michigan, Ann Arbor, Mich.

THE IMPACT OF NUCLEAR ENERGY ON RELIGIOUS THOUGHT, Elton Trueblood, Department of Philosophy, Earlham College, Richmond, Ind.

Thursday, June 24, P.M.

TECHNICAL SESSION No. 15
(Simultaneous with Session No. 16)

Applications and Uses of Radioactive Products I

Chairmen—L. E. Brownell and J. M. Otero

THE CHEMICAL POTENTIAL OF WASTE FISSION PRODUCTS, E. J. Henley, Columbia University, New York, N. Y.

CHLORINATION OF SOME AROMATIC COMPOUNDS UNDER THE INFLUENCE OF GAMMA RADIATION, D. E. Harmer, L. C. Anderson, and J. J. Martin, University of Michigan, Ann Arbor.

GAMMA RAY INITIATED POLYMERIZATION OF STYRENE AND METHYL METHACRYLATE, D. S. Ballantine, P. Colombo, A. Glines, and B. Manowitz, Brookhaven National Laboratory, Upton, N. Y.

KINETICS OF THE ETHYLENE REACTION INITIATED BY GAMMA RADIATION, J. C. Hayward, Jr., and R. H. Bretton, Yale University, New Haven, Conn.

POLYMERIZATION OF ETHYLENE BY GAMMA RADIATION, J. G. Lewis, J. J. Martin, and L. C. Anderson, University of Michigan, Ann Arbor.

NON-TECHNICAL SESSION, No. 14
(Simultaneous with Session No. 15)
Social Impact of Nuclear Energy II

Chairman—F. J. Van Antwerpen

THE IMPACT OF NUCLEAR ENERGY ON EDUCATION, Harlan Hatcher, president, University of Michigan, Ann Arbor, Mich.

THE IMPACT OF NUCLEAR ENERGY ON MILITARY TACTICS, S. L. A. Marshall, *Detroit Times*, Detroit, Mich.

THE IMPACT OF NUCLEAR ENERGY ON SCIENTIFIC RESEARCH, Lloyd V. Berkner, president, Associated Universities, Inc., New York.

THE IMPACT OF NUCLEAR ENERGY ON THE LAW, E. Blyth Stason, Law School, University of Michigan, Ann Arbor, Mich.

Friday, June 25, A.M.

TECHNICAL SESSION No. 17
(Simultaneous with Session No. 18)

Applications and Uses of Radioactive Products II

Chairmen—C. R. Horner and O. O. M. Gamba

THE USE OF THE IONIZATION POWER OF NUCLEAR REACTORS FOR PROFITABLE CHEMICAL PROCESSES, B. Manowitz, Brookhaven National Laboratory, Upton, N. Y.

DESIGN OF A GAMMA RADIATION FACILITY FOR TREATING PORK, H. J. Gomberg, S. E. Gould, L. E. Brownell, and J. V. Nehemias, University of Michigan, Ann Arbor.

RADIOISOTOPES IN INDUSTRIAL CONTROL, G. D. Calkins and M. Poberesкin, Battelle Memorial Institute, Columbus, Ohio.

GROWTH OF RADIOISOTOPE UTILIZATION IN INDUSTRY AND ENGINEERING, P. C. Aebersold and C. E. Crompton, Atomic Energy Commission, Oak Ridge, Tenn.

TECHNICAL SESSION No. 18
(Simultaneous with Session No. 17)

Nuclear Power Reactors II

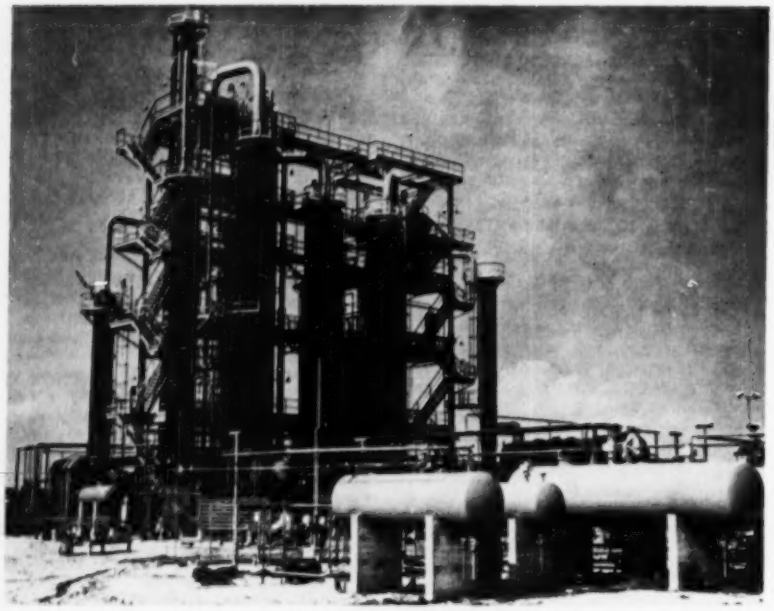
Chairmen—W. H. Zinn and L. Hafstadt

BIGGER GOALS FOR NUCLEAR ENERGY, J. J. Grebe, Dow Chemical Co., Midland, Mich.

NUCLEAR POWER—THE ECONOMIC APPROACH, T. Le Clair, Commonwealth Edison Co., Chicago, Ill.

(Continued on page 70)

NEW STYRENE MONOMER PLANT ON STREAM



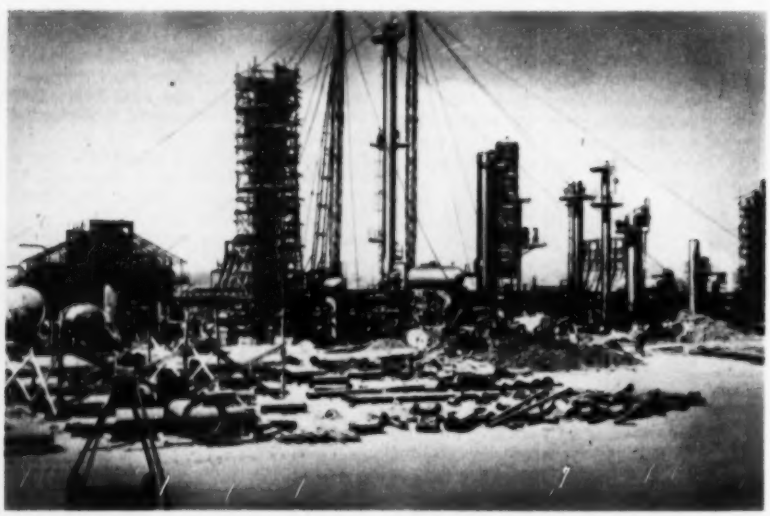
Fractionating columns used in the purification of styrene at Foster Grant's new Baton Rouge styrene monomer plant.

Completion of a new petrochemical plant for the production of styrene monomer, the first plant of its kind in the United States, according to Foster Grant Co., was announced by that company last month. Within one corporate structure the entire cycle of production from purchase of refinery materials to the final merchandising of plastic products is completed. The $4 million plant is located in Baton Rouge, La.

Employing certain chemical processes initiated in Germany, the plant was laid out by F. D. Mayfield, plant manager. It is almost completely automatic and can be run continuously by thirty-five employees with the aid of 250 instruments for automatic control. Full-production capacity is expected to be about 2 million pounds of styrene monthly.

Ethylene and benzene, the primary raw materials, are received from the near by Esso refinery, and following alkylation the ethylbenzene is separated by distillation. Unreacted materials and undesirable higher alkylates are recycled. The ethylbenzene is mixed with steam and catalytically dehydrogenated. Distillation separates out the monomer and small amounts of by-product, and the unreacted ethylbenzene is recycled through the dehydrogenator. The purified styrene monomer is collected in refrigerated tanks and shipped in insulated tank cars. It is polymerized in the firm's plant at Leominster, Mass.

CHILE ENTERS OIL-REFINING FIELD



The first refinery to be erected in Chile is being completed about 10 miles north of Valparaiso. Designed and engineered by The M. W. Kellogg Co. for Empresa Nacional del Petroleo, the refinery is expected to be on stream this summer. Both native and imported crude oils will be processed by the plant, which will have a daily capacity of 20,000 bbl. Products will include liquefied petroleum gas, motor and tractor gasoline, kerosene, two grades of diesel oil, and heavy fuel oil.

U. S. GETS FIRST ACETYLENE PLANT

A $6 million plant for the manufacture of high-pressure acetylene products has been announced for construction at Calvert City, Ky., by General Aniline & Film Corp. Expected to be completed by the end of 1955, the plant will incorporate many features of the company's pilot plant at Linden, N. J., opened in March, 1949. The first plant in this country for commercial manufacture of high-pressure acetylene products, the new installation will use processes centered on two basic techniques, the dilution of acetylene with an inert gas and the use of small-bore equipment to provide a minimum of free space in which gases might collect to form a hazard.

Acetylene was discovered by the English chemist Edmund Davy in 1836 but not until 1892 was a practical method of making it developed. By the beginning of World War I acetylene had become established as a fuel for welding torches and as a raw material for certain low-pressure methods of making a small number of acetylene chemicals. Shortly before World War II, techniques were developed in Germany to use the ordinarily explosive gas under high pressures and at elevated temperatures to make a much wider variety of products than are obtainable by the low-pressure methods. Some of these products filled Germany's wartime needs for essential components of synthetic rubber, pharmaceuticals, and synthetic fibers.

In 1940 General Aniline initiated an intensive program in this field and was able to supply the American war effort with Polectron, a substitute for mica in electronic applications, and Koresin, a tackifier for synthetic rubber, both derivatives of acetylene.

The plant will concentrate at first on the P.V.P. family of acetylene derivatives. Another family of high-pressure acetylene derivatives now under sales development is the vinyl alkyl ethers and esters and their polymers.

(*More News on page* 44)

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LATTICE BRAID packing (a patented Garlock product) is braided through and through to give it strength, flexibility, resiliency, and long life. Teflon (a du Pont product) is unaffected by caustics, process liquids, solvents, acids or chemicals of any kind.

Garlock combines these two products by impregnating each strand of LATTICE BRAID asbestos packing with Teflon suspensoid. The result is a sturdy braided asbestos packing with a heavy, thoroughly distributed Teflon impregnation which is unaffected by the liquid being handled. This long-life packing has a low coefficient of friction, is non-corrosive and non-contaminating.

LATTICE BRAID with Teflon is available in either Canadian white asbestos (Style 5861) or blue African asbestos (Style 5880). Garlock also manufactures all-Teflon LATTICE BRAID packing, plastic packings of shredded Teflon, and other Teflon products.

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AID IN ATOMIC ENERGY AVAILABLE IN NEW YORK

The Atomic Industrial Forum, Inc., 260 Madison Ave., New York City, has agreed to activate June first and maintain a special collection of technical reports and equipment drawings, according to Dr. Alberto F. Thompson, chief of the technical information service of the Atomic Energy Commission. This collection, for which the A.E.C. has already agreed to provide a nucleus including a selection of nearly 1000 of the most significant publications, is intended particularly for industrial use. There are now more than 40 A.E.C. depository libraries around the country, but these are primarily for scientific and academic audiences. Further information about access to the Forum facilities may be had by contacting Edwin Wiggin, manager of technical information. He was previously chief, isotopes development branch, Atomic Energy Commission, Oak Ridge, Tenn.

EQUIPMENT TESTING CODE RELEASED BY A.I.Ch.E.

A tentative nomenclature code has been issued by the Agitators Subcommittee of the Equipment Testing Procedures Committee and copies may be had by writing to J. Y. Oldshue, Mixing Equipment Co., 135 Mt. Read Blvd., Rochester 11, N. Y.

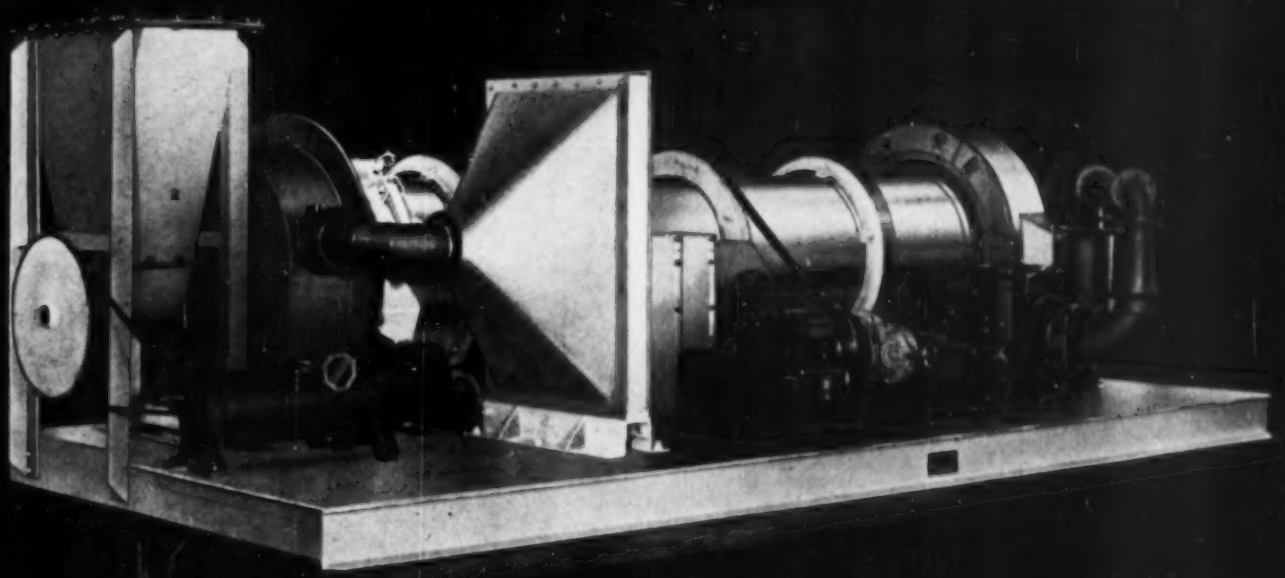
This nomenclature code is the first step in the development of test procedures intended to bring about common agreement between the customer and the manufacturer of mixing equipment.

While the Agitator Sub-committee will ultimately prepare such codes for impeller, paste and dough, and dry mixers, the present committee is specializing in the impeller type. The nomenclature referred to above relates only to that type.

INTERNATIONAL MEETING IN BRUSSELS IN FALL

The Twenty-seventh International Congress of Industrial Chemistry will be held in Brussels from Sept. 11 to 19, 1954. Among the sections for which papers may be submitted are those on chemical engineering; corrosion; solid and gaseous fuels; liquid fuels and petroleum products; petrochemistry; nuclear sciences; heavy-chemicals industry; plastics; fatty substances; organic industries; and industrial, professional and commercial organization. Information may be obtained from the Secretariat, 32 Rue Joseph II, Brussels, Belgium. The deadline for submitting papers is July 15.

(More News on page 47)



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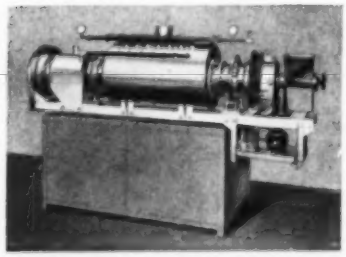

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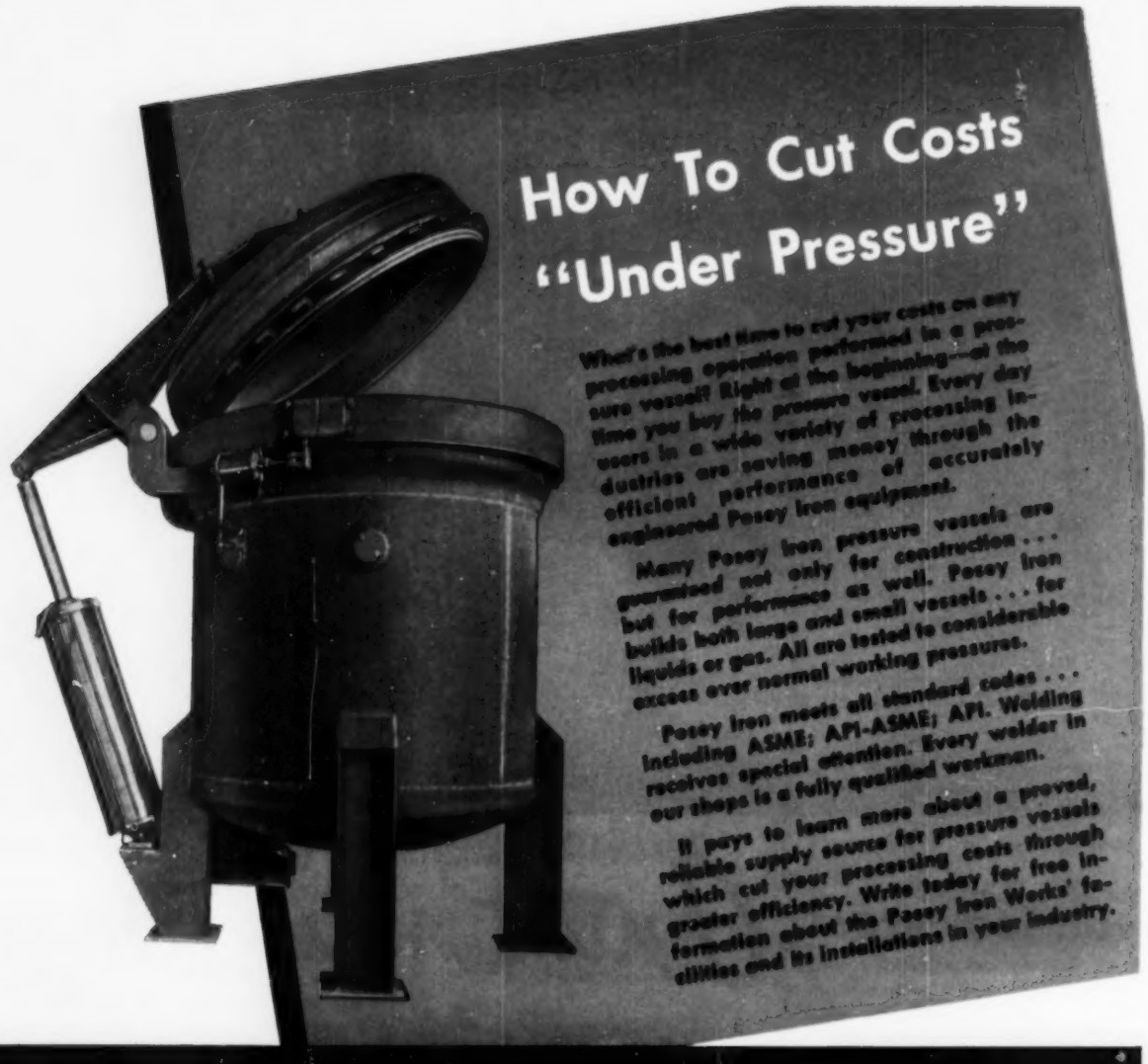

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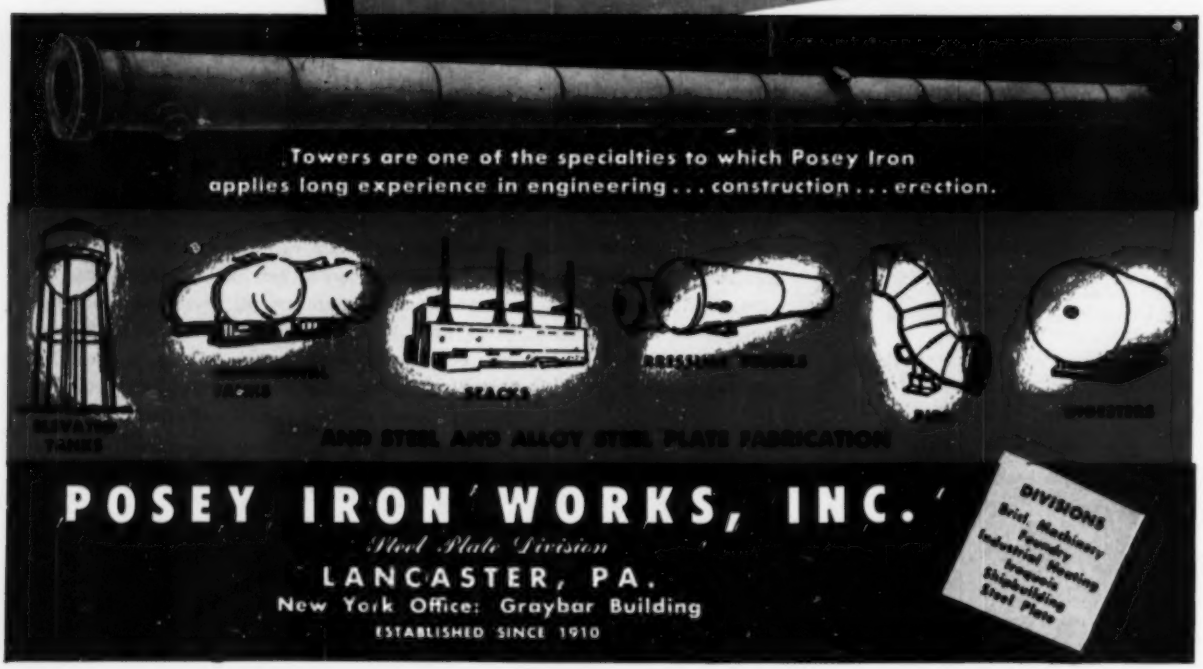
Towers are one of the specialties to which Posey Iron
applies long experience in engineering . . . construction . . . erection.
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A.E.C. DEVELOPS NEW X-RAY UNIT

A small, inexpensive, portable x-ray unit potentially useful in industry and medicine has been developed at Argonne National Laboratory of the Atomic Energy Commission. The active component of the instrument is a tiny particle of thulium that has been made radioactive in the heavy-water nuclear reactor at Argonne. The thulium is mounted in a source holder and shield equipped with a shutter mechanism operated by a standard photographic cable release. Weighing less than 10 lb., the unit provides rays comparable in energy to a 100,000-volt x-ray machine, but no electrical power supply is required, as in conventional x-ray equipment.

Industrially the unit may find use as a density-determination device, especially of liquids in closed systems.

INDUSTRIAL GROUP STUDIES NEW REACTOR

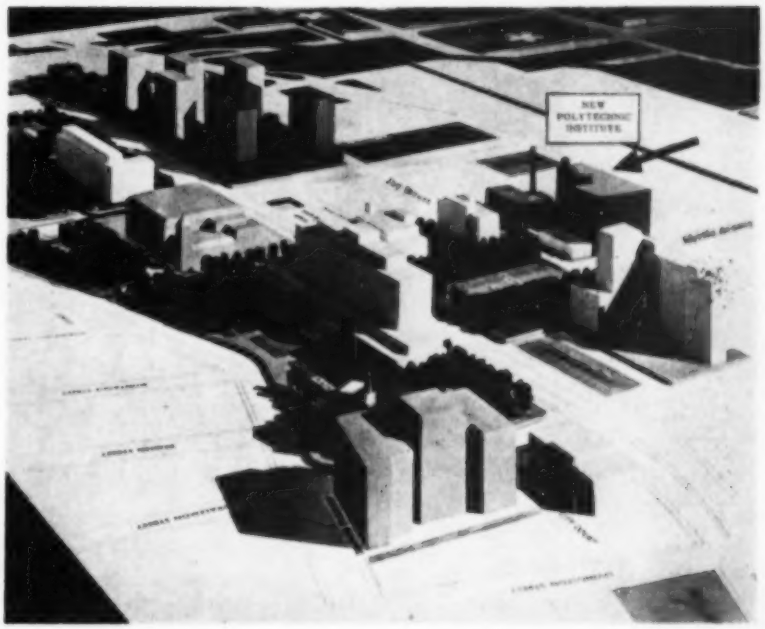
Nuclear-power investigations involving actual experiments and preliminary engineering for development of a breeder reactor for the generation of electric power and other products have been approved by the Atomic Energy Commission for the Dow Chemical Co.—Detroit Edison Co. industrial study group, which includes twenty-six associated firms or groups of firms.

An estimated $2,000,000 will be spent by the group in industry-owned research facilities. When specific research projects can best be carried out in A. E. C. facilities, this may be done at the group's expense if no A. E. C. project has higher priority. About $300,000 will be spent on such work and an equal sum will be devoted to investigations requiring work of direct interest to the A. E. C. and forming part of its approved program. The latter work will be supported by the A. E. C. The new arrangement will continue until Jan. 31, 1955.

VITAMINS SUPPORT WEST GERMAN RESEARCH

A new West German grants program has been inaugurated by Research Corp., according to a recent announcement. The $30,000 program, which will support fundamental research, will be financed from royalties collected in Germany on American patents for the manufacture of vitamin B_1. The patents were assigned to the nonprofit corporation in 1935 by the inventors, Robert R. Williams, Robert E. Waterman, and their associates. Royalties earned in the postwar period plus those to be collected during the remaining life of the patents are expected to be sufficient for a 5- to 10-year program of the present scope.

BROOKLYN POLYTECH FINDS NEW HOME



Structures recently contracted for purchase by the Polytechnic Institute of Brooklyn from the American Safety Razor Corp. (indicated by arrow) face the area that will become Myrtle Park in the new $80,000,000 civic center planned for downtown Brooklyn, N. Y. At the opposite end of the park will be the new Supreme Court building soon to be erected. The low white model in front of the gray models of the institute buildings represents the projected library and student lounge.

The Polytechnic Institute of Brooklyn announced last month the prospective purchase for $2,000,000 of an eight-story, block-long plant building of the American Safety Razor Corp. in downtown Brooklyn. Plans are to consolidate the Polytech facilities now scattered among a number of outmoded buildings in the area.

The new building is located on Jay Street between Johnson Street and Myrtle Avenue, accessible to the many employed evening students. Having been originally designed for industrial loads, the building will be suitable for the machinery required in engineering laboratories.

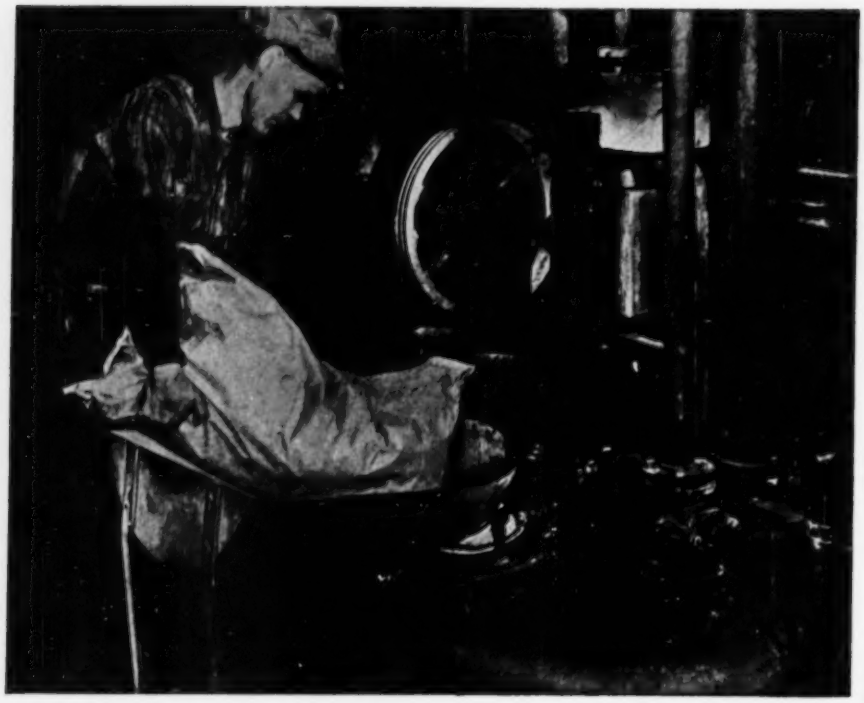
No date for the institute's move into its new quarters has been determined, as funds have still to be raised, a goal of $3,500,000 having been set for adapting the plant to educational purposes and purchasing adjacent properties for a proposed new library and for a student lounge.

NUCLEAR ENERGY TO BE STUDIED BY 3 FIRMS

A survey and study of the Atomic Energy Commission's reactor development activities in relation to equipment aspects of nuclear power development has been announced by the Babcock & Wilcox Co. The agreement is independent of other studies that the company is making for the A.E.C., and costs are to be borne by the Babcock & Wilcox Co. A supplier of atomic-energy equipment for use in national laboratories, the company, according to C. H. Gay, vice-president in charge of its atomic energy division, "is looking forward to the time when it can assume a position as an equipment supplier in the nuclear power business similar to the position it now occupies in the conventional power business."

Two other companies also carrying out independent atomic energy studies for the A.E.C. are Bendix Aviation Corp. and American Machine and Foundry Co. The Bendix study will deal with the future of atomic power and by-products, anticipating the development of new reactor designs and the discovery of new uses for radioactive isotopes or fission products. American Machine and Foundry will make a study of machines and equipment associated with nuclear power plants and will explore the feasibility of developing low-power reactors for industrial research. The company has been concerned in the development and manufacture of control mechanisms for atomic-energy installations.

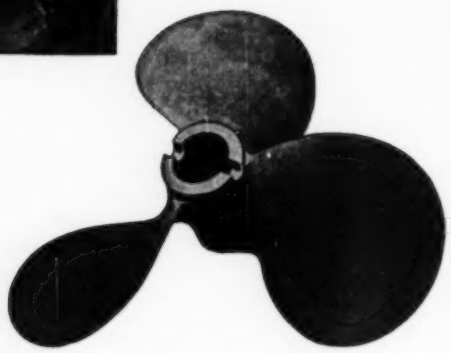
(More news on page 68)



Trouble-Free Production of Intermediates by Zinsser and Company, attests to the exceptional corrosion resistance of propellers, shafts, thermometer wells and blow-off lines fabricated from one of the high nickel-base alloys trade-named "Hastelloy," produced by Haynes Stellite Company, Kokomo, Indiana, a Division of Union Carbide and Carbon Corporation.

Still Good After 5 Years

in Hot H_2SO_4 and HCl



High Nickel-Base Alloy Cuts Maintenance. This propeller, made from HASTELLOY alloy D, is still in use after five years . . . mastering corrosion that caused propellers made from other materials to fall off and chip the kettle lining. Repairing kettles and replacing propellers were expensive maintenance items, heretofore.

Control of drastic corrosion has made possible the continuous trouble-free manufacture of intermediates during the past five years by Zinsser and Company, Hastings-on-Hudson, N. Y.

Zinsser uses a process that involves adding various aromatic organic chemicals, some of which contain chlorine, to a solution containing sulphuric acid. Since the solution is held in several 500-gallon kettles which are heated to 200° C., severely corrosive conditions arise from the resulting hydrogen chloride gas formed at this high temperature.

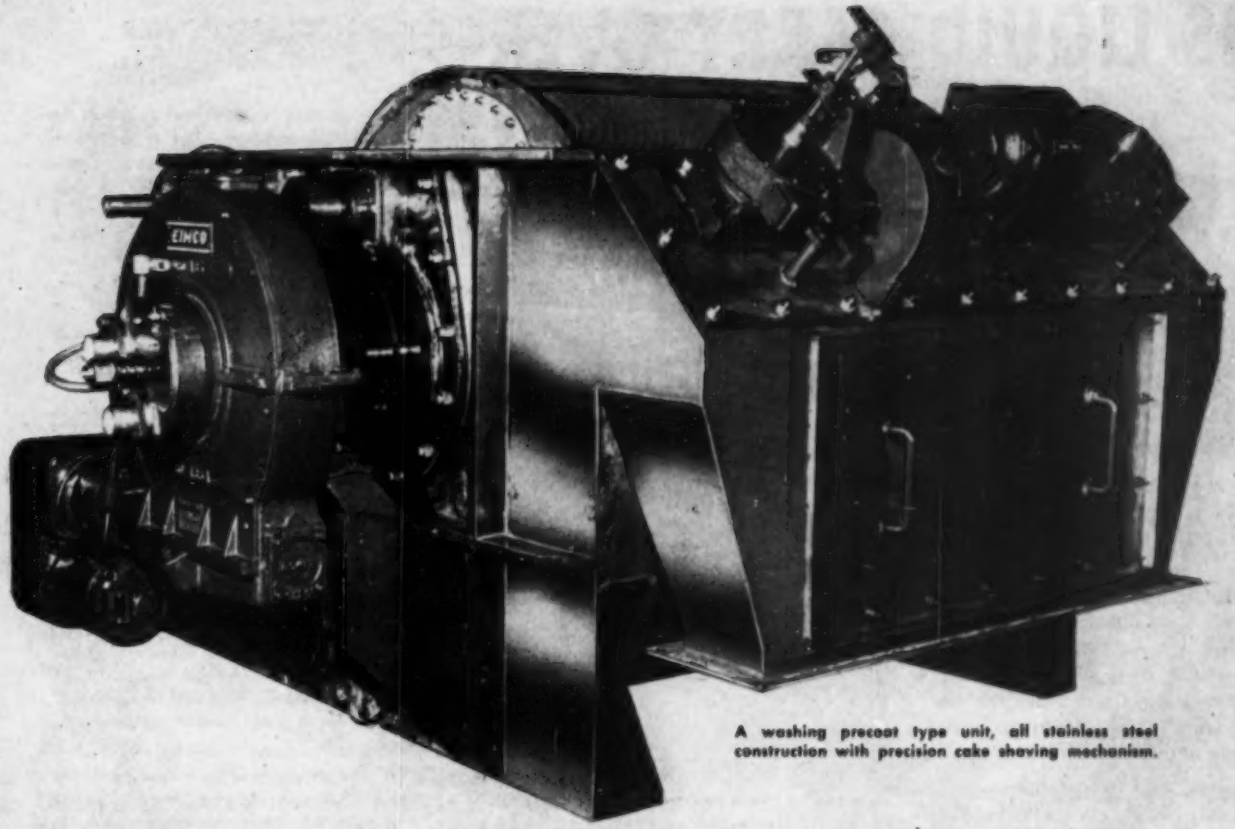
Nevertheless, a high nickel-base alloy . . . trade-named HASTELLOY alloy D . . . solves this particular problem, just as it has solved many others where exceptional corrosion resistance is needed at high temperatures.

Prior to using HASTELLOY alloy D, Zinsser found that equipment had to be replaced about every three months. Various materials were tried, but no improvement resulted until the high nickel alloy was put into service more than five years ago. And . . . it is still in use, reducing maintenance costs.

Wherever you encounter strong corrosives at high temperatures, let us help you. We offer counsel and data based on years of practical experience. Send details of your problem for our suggestions. Write today.

"Hastelloy" is a registered trade-mark of Union Carbide and Carbon Corporation.

THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET NEW YORK 5, N.Y.



A washing precoat type unit, all stainless steel construction with precision cake shaving mechanism.

Washing Precoat Filtration Units

Specialized Eimco filtration units do a better job than standard filtration units where the metallurgy is complicated and the savings are critical.

Here is another typical example of a specialized application where Eimco design and construction played an important part with a consequent greater saving to the customer.

The subject plant was using standard filter press equipment for extraction of a valuable copper sulphate solution from the slurry. A 2% copper sulphate content in the feed was filtered on a unit similar to the one pictured and reduced the CUSO4 to less than 0.5% where as the best obtainable in the presses had been between 0.6—0.7%. Flow rates on the filtrate were increased from .8 gallons/sq. ft./hr. to 4—4.5 gallons per sq. ft. per hr. on a 24 hour basis. Clarity of the filtrate from the Eimco unit was better at all times. Less wash water was used with a resultant lower dilution factor.

More than half a century of experience in serving the process industries, plus unsurpassed research and laboratory facilities make it possible for Eimco to recommend the best type of unit for your process.

Write for more information to The Eimco Corporation, Box 300, Salt Lake City, Utah.

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IS LIQUID CARRY OVER-

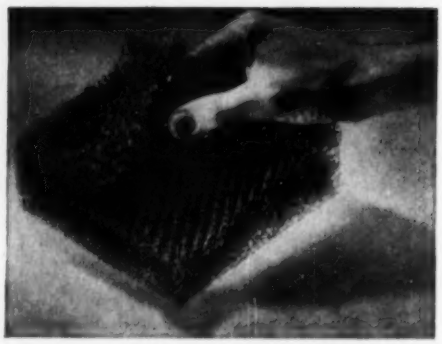
LIMITING YOUR PRODUCTION?

AFFECTING PRODUCT PURITY?

CUTTING INTO YOUR PROFITS?

IF SO

GET THE FACTS ON METEX MIST ELIMINATORS!

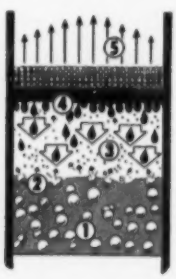


Section of a METEX MIST ELIMINATOR, opened to show construction. Factory cut to fit vessel dimensions and contour, there is no limit to the size in which they can be obtained. They can be made of practically any metal, to combat corrosion.

These separators, which are made from layers of knitted wire mesh, literally "filter out" the liquid droplets by impingement and accumulation in depth (see diagram). The liquid is returned by gravity: The gas passes on freed from the unwanted—and often contaminating entrainment.

METEX MIST ELIMINATORS can be easily installed in new or existing vessels. Special housings are not needed, and they have no moving parts to require power and servicing. They will function over an unusually wide range of velocities with a pressure drop generally well under 1" of water. Efficiencies of 99% and over are commonly reported.

While liquid entrainment is an inevitable result of practically any processing operation involving the handling of liquids and gases together, it need no longer be considered as an unavoidable evil. It can be controlled simply, effectively and economically – by a Metex Mist Eliminator, as more and more engineers are finding from experience.



When a gas is generated in or passes through a liquid (1) it carries with it on leaving the surface (2) droplets of entrained liquid. These droplets are carried upward by the rising gas stream (3). As the gas continually changes direction in passing through the pad, the droplets are impinged on the extensive wire surface. Here the droplets coalesce, forming large drops of liquid which break away (4) from the pad and fall back through the gas stream. The gas (5) passes on, freed from liquid entrainment.

Write TODAY for free catalog giving complete information and engineering data. Or tell us about your SPECIFIC entrainment problem.

METAL TEXTILE CORPORATION

KNITTERS OF WIRE MESH FOR MORE THAN A QUARTER CENTURY

METEX

Roselle, New Jersey

NUCLEAR POWER

(Continued from page 36)

strength and size of the vessel in which the reactor must be contained. One of the difficult problems will be that of getting control mechanisms to operate in a high-pressure vessel. Principally, the objective is to learn how such a plant may stand up under ordinary operating conditions of central station electric power plant and how much it will cost to build and operate. There are no expectations that this reactor will produce power as cheaply as a modern coal-burning plant, but possibly one can learn how costs can be cut in later plants.

The *second* new reactor which is projected in the program is a breeder of intermediate size. It will not be of direct interest from the point of view of economic power, but it will be much larger and much more nearly a power-producing, continuously operating reactor than the small experiment which has been running out in Idaho. The scale-up planned is from 1,400 to 62,500 kw. of heat, and from 170 to 15,000 kw. of electric power. Temperatures and steam pressure will be increased to values appropriate to a full-scale power breeder reactor. Auxiliaries such as pumps, heat exchangers, valves, etc., will be of sizes suitable to a full-scale reactor.

The *third* step is based on the boiling experiment which has already been described. It will be an attempt on an intermediate scale actually to use boiling of the water as a method of heat extraction. It is hoped in this way to get a very cheap method of getting the heat out of the reactor and possibly of eliminating one step between the coolant in the reactor and the turbines which turn the generator. *It is planned to feed the steam generated in the reactor directly to the turbines.* Present plans call for 20,000 kw. of heat and 5,000 kw. of electric power.

The *fourth* reactor which, it is the intention to build, is a larger version of the homogeneous reactor. Again, it will be a step in the direction of a practical power-producing unit and should give information about corrosion, chemical processing, and operating conditions that cannot be obtained with the small machine now in use at Oak Ridge. Present specifications call for only 3,000 kw. of heat in this reactor experiment compared to 1,000 in the present experiment. The next step, already planned, calls for 65,000 kw. of heat in a homogeneous reactor which will breed U^{233} in a blanket of thorium surrounding the chain-reacting core.

The *fifth*-reactor experiment which is planned is a little different from any described here. It was mentioned in this paper that the breeder reactor uses sodium-potassium alloy as a coolant. It is well known that the Hanford reactors use graphite as a moderator. The idea is to combine these two materials, to get the advantage of high temperature without high pressure from the sodium coolant. To test this combination, a reactor will be built generating about 20,000 kw. of heat but without any electric generating plant attached.

(Continued on page 54)

This MARLEY Cross-Flow has no secrets from the operator . . .

Open gravity distribution is one of the exclusive design features of Marley Cross-Flow cooling towers that makes them so "easy to live with" — and so economical to operate.

Is the water loading correct in every basin? Is the water flowing freely to every part of the tower fill? Are the basins clean? One glance and the operator of a Marley Cross-Flow has all the answers. And he takes that glance while making his inspection from a safe walkway. There is no need to subject himself to the hazards and discomfort of climbing into the tower to ascertain conditions.

If a change in water loading is desired, the valve is at hand and the variation in flow is visible. Since no pressure is required, increase or decrease in flow will not impair operating efficiency. No part of the fill will be starved; no part of the fill will be flooded.

Should a basin require cleaning, it is the work of minutes to shut down only the basin needing attention, clean it with complete safety and restore it to operation.

. . . a single glance tells you where you stand!

Open distribution and many other advantages of Marley Cross-Flow Cooling Towers are explained in Marley's new 32-page bulletin CF-54.

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Founder-Member Cooling Tower Institute — Kansas City, Missouri

MARLEY

MARGINAL NOTES

News of Books of Interest to Chemical Engineers

The Dean's List

Report on The Atom. Gordon Dean, formerly Chairman, U. S. Atomic Energy Commission. Alfred A. Knopf, New York (1953), xiii + 321 pp. $5.00.

This is essentially a friendly book, one that may be enjoyed by the general public without fear of being overwhelmed with technical details, one that may be enjoyed by the technical world because of the wealth of insight and behind-the-scenes information that the former chairman of the Atomic Energy Commission gives. And this is exactly what Gordon Dean planned to do, for in the preface he states that, when he was first trying to orient himself in the Atomic Energy Commission, he "soon discovered . . . there was much information . . . either too technical or altogether too popular . . . . Unfortunately . . . there was very little in between these two extremes; very little, that is, that attempted to describe the atomic energy program itself or to convey a real feeling for the many great problems which face the nation in the atomic energy field." This is exactly what was turned out, and often, when the problems facing the Commission are described, one feels not only the load of work but also the honest gamble that must go into executive decisions.

There are many chapters of fascinating interest. Two especially appealed to this reviewer, "The Expanding Program," and "The Headaches." In both these chapters Dean tells of the difficulties involved in the buildup of the A.E.C. program in the U. S.

When the Manhattan District turned over its assets to the civilian commission, the capital investment was $1,004,000,000. It climbed to $5,000,000,000 and the expansion since the cold war will add another $4,000,000,000. Dean takes the reader through all the steps from the determination of the need, the determination of the size, proving the need, securing Congressional approval and the troubles that go with it, to the completion of the program.

He also tells of the Commission's decision to build three barracks of 4,500 beds at the Savannah River site for construction workers and how they were never, at any time, more than 25 per cent occupied. The reasons, as traced down later, are a lesson in why ulcers plague executives. Careful calculation of the number of single men to be expected in the work force who normally would be expected to use barracks, proved in error for the Savannah River project—the figures work for all other A.E.C. installations—but at Savannah River, 80 per cent of the work force consisted of married men who preferred trailers. This is high and created a demand for trailers but not for barracks. On top of that the local rent-control board placed a rental ceiling well below the minimum the A.E.C. had guaranteed to the private concern owning the trailers, an act which will cost the government millions of dollars. As Dean says, "There are a good many other reasons why you will find packages of aspirin tablets in a large percentage of the desks around Commission headquarters in Washington."

Another important point stressed is the progress "Behind the Iron Curtain." In contrast to popular opinion that Russia is woefully behind the rest of the world in scientific matters, Dean marshals many instances of Soviet progress to show that this idea is wrong and that Russia is already an important factor in science. The number of higher educational institutions in Russia, he says, has increased from 150 in 1930 to 900 in 1952.

Student enrollment has gone up from 200,000 to 1,400,000. Annual graduating classes now total 200,000, about half technical and scientific personnel. This compares with our annual total of 100,000 technical students in the United States.

As for engineers, 30,000 graduated in Russia in 1952, and by 1955, 40,000 will be trained annually.

Dean lists a nine-point program for progress in the atomic age which space precludes listing, but the last paragraph in the book deserves quotation:

Mankind has recently entered a room, the door to which is labeled the atomic age. We are in that room, and we cannot yet begin to perceive all that is in it. But we have crossed the threshold, and we cannot turn back. All we can do is go forward as boldly, and yet as wisely, as we can. One of the great responsibilities that we in America assumed when we brought the atomic bomb into the world was to lead the way to the atomic age. To do it well, our statesmen will need the understanding, the guidance, and the help of every citizen.

F.J.V.A.

Manpower Utilization

Proceedings of a Conference on the Utilization of Scientific and Professional Manpower. Columbia University Press (1954), 197 pp. $3.50.

Reviewed by W. T. Cavanaugh Executive Secretary Engineering Manpower Commission, Engineers' Joint Council.

This book presents the results of the Arden House conference sponsored by the National Manpower Council held Oct. 11-17, 1953. Five or more months that have passed have not lessened or altered the basic problems relative to the efficient use of American brainpower, nor are they any less urgent despite the Korean armistice and the current economic situation. For this reason it is good that industry and the medical and teaching professions have access to the thinking that has been, until now, the property of the sixty-six conferees.

Almost everyone who is informed about the limitations of the highly trained professional personnel will wish that gift copies of the book might be sent to a short list of public officials, administrators, and policy-makers. It would do no harm for them to read again that

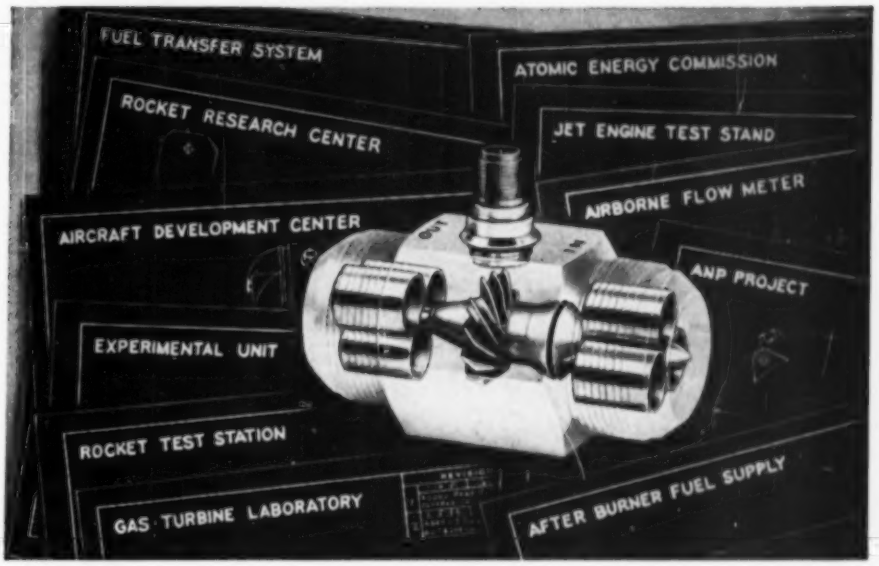
. . . it is indefensible to insure a continuous, large supply of highly educated men through a student deferment program and then risk the waste of their skills and competence by poor assignments in the armed forces . . . the effective utilization of educated and highly trained men must be a continuing objective of national manpower policy.

Major problems of utilization are introduced by James D. Zellerbach, president of the Council, and are elaborated in papers by Kenneth E. Boulding, professor of economics, University of Michigan; Frank Pace, Jr., executive vice-president, General Dynamics Corp.; and Seymour L. Wolfbein, chief, division of manpower and employment, Bureau of Labor Statistics.

Effective utilization of engineering personnel was considered by a panel of eighteen conference members, who seemed as gravely concerned with the supply of engineers as with problems of utilization, despite George M. Maverick's caution that the economic outlook indicates the wisdom of stressing quality and of de-emphasizing quantity. In the

(*Continued on page 60*)

Potter Flowmeter First in Nuclear Research

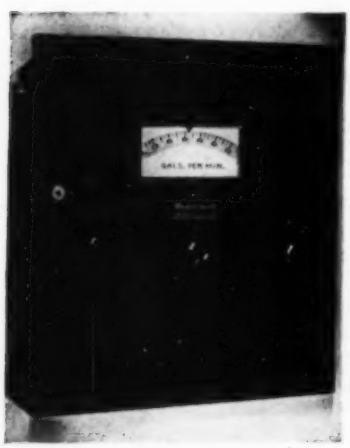


This unique flow sensing element, able to withstand high pressures and high or low temperatures, has brought a new standard of accuracy to flow measurement in test and research work. Constructed of high-grade stainless steel to avoid contamination of the measured liquid, it is being used in many nuclear engineering projects.

ATOMIC RESEARCH INSTALLATIONS throughout the United States and Canada have adopted the Potter Flowmeter as their standard for accuracy. Simplicity, stability, dependability and ruggedness, combined with an ability to operate at high accuracy in either the vertical or horizontal position are only a few of the features that have caused nuclear physicists to specify Potter for flow measurement in new installations.

HEAT TRANSFER LIQUIDS are measured easily and accurately with the Potter unit, which is easily installed and will operate for prolonged periods of continuous use with no maintenance. The operating pressure of Potter insertion-type sensing elements is limited only by the strength of the pipelines in which they are used. Installations operating at 35,000 psi are not uncommon.

NUCLEAR POWER PROJECTS are utilizing Potter systems because they operate without servicing, and because sensing elements can be fabricated from materials selected to avoid contamination of highly refined heat transfer fluids. Units can be operated at temperatures as high as 1100° F.



Twenty-eight inch rotating disc scale gives Potter-Brown Flow Indicator superior legibility.

ACCURATE READING of flow rates has been made possible through the development of instruments whose precision approaches that of the Potter sensing element. The Potter-Brown Precision Flow Indicator has a scale with a graduated length of 28 inches, marked with as many as 600 divisions. Since the flowmeter is linear, legibility is excellent at high or low flow rates. If necessary, the effective scale length can be doubled by using a dual scale.

RECORDING flow on either a circular or strip chart provides permanent test records. The Potter-Brown Strip Chart Recorder, having a graduated width of ten inches and available in a variety of chart speeds provides accuracy, convenience, and ease of reading.

TELEMETERING SYSTEMS can be easily designed around the Potter element, which produces a frequency output suitable for transmission by wire or radio.

CLASSIFIED labels are on many of the projects in which Potter equipment is being used; but many users are able to give reports on the operation of their Potter flowmeters. If you are measuring flow and you are not already using the Potter Flowmeter, ask your associates and acquaintances in the industry about this new method of measuring flow. Their experience may help you to solve your flow metering problems.

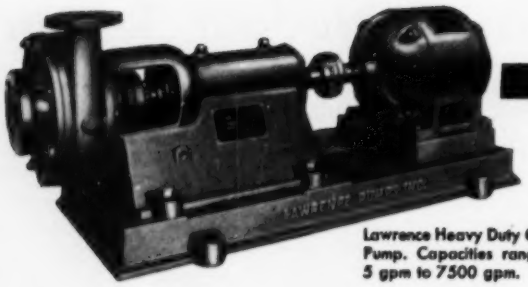
FOR FURTHER INFORMATION send a description of your flow metering application and the type of instrumentation required to:

POTTER AERONAUTICAL COMPANY

Route 22 — UNION, N. J.

Sales Offices:

87 Academy Street, Newark 2, N. J. — Phone: Mitchell 2-5525



Lawrence Heavy Duty Chemical Pump. Capacities range from 5 gpm to 7500 gpm.

HORIZONTAL

ACID and CHEMICAL PUMPS

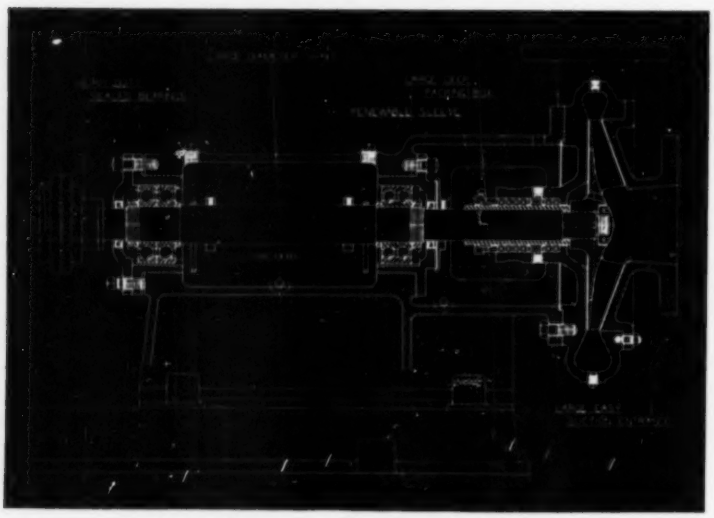
No class of service puts a more exacting duty upon pumps than the chemical and process industries. The problem is not simply the handling of a fluid, but of resisting the destructive action of the fluid itself.

In this difficult field Lawrence engineers have had repeated and successful experience with practically every "pumpable" fluid. The range of materials pumped includes all kinds of acids, caustics, dye solutions, bleach solutions, various oils, syrups, fruit and vegetable juices, pulps, and liquids carrying a high percentage of abrasive or solid matter in suspension.

The metals and alloys used in Lawrence acid and chemical pumps are carefully selected for their ability to resist the corrosive and abrasive action of the liquid pumped. Those most commonly used are: stainless steel, nickel, Monel, bronze, Hasteloy, Ni-resist, lead, aluminum, iron and steel.

If your problem involves pumping acids, chemicals or slurries write us the pertinent details. No obligation.

Write for Bulletin 203-6 for summary of acid and chemical pump data.



Cross-section of Lawrence Heavy Duty Chemical Pump.

LAWRENCE PUMPS INC.

371 MARKET STREET, LAWRENCE, MASS.

NUCLEAR POWER

(Continued from page 50)

In addition to these new proposals, several other programs already under way will be continued. These include development of the so-called intermediate submarine reactor and the development of a reactor to propel aircraft.

Costs

The Atomic Energy Commission believes that power can be produced cheaply enough to be of general use, and this is the opinion also of the several private industrial groups who have been studying the problem for several years at the invitation of the Commission.

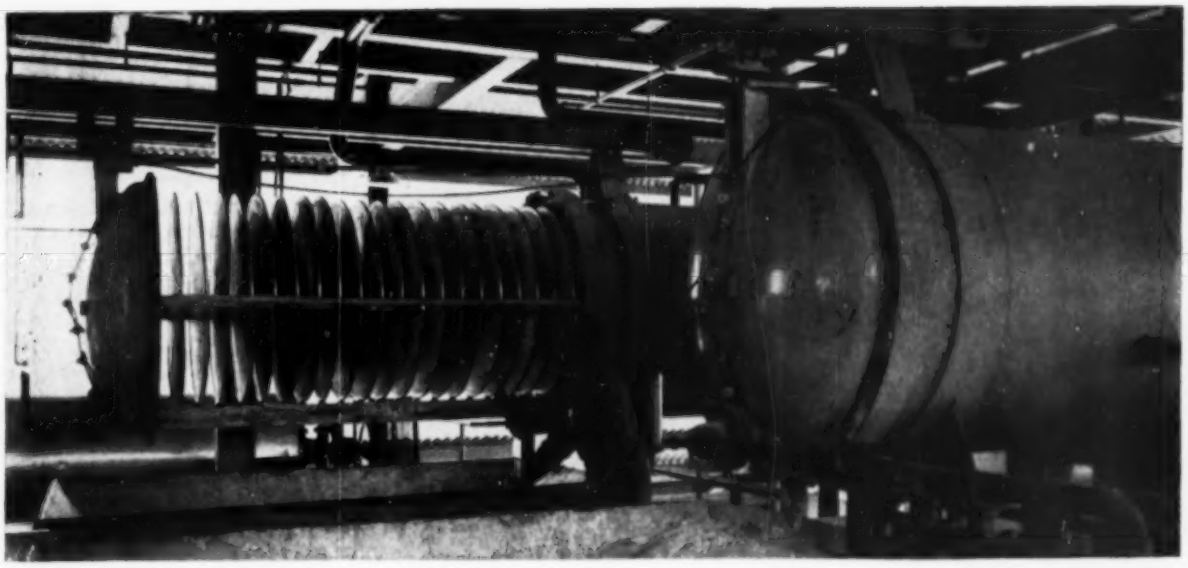
Industrial Participation

Private industrial groups have assigned able members of their staffs to design studies of nuclear power plants and in some cases are doing considerable amounts of research at their own expense. But it is a mistake to think that private industry can or will pick up the burden of development of nuclear power plants in the present state of the art. It is a field in which knowledge and competence are still largely confined to Government laboratories and in which the financial risks are still too great for private industry to carry alone.

The Commission hopes for greater participation by industry both technically and financially and for a gradual transfer of the nuclear power part of the Commission's responsibilities to private enterprise. The problems of such a transfer are just about as difficult to resolve as the technical problems of getting cheap nuclear power. Time, money, and thought will be needed for both sets of problems. It is believed they can be solved.

Conclusion

To establish a nuclear power industry in this country will be a great achievement. If power becomes cheaper and more plentiful, the material standard of living will be raised. In other countries the effect may be even greater. By the accident of history the first use of this great new discovery has been in the development of weapons of war, weapons of appalling magnitude. The nations of the world have today the means to destroy one another. They also have, in this same nuclear energy, a new resource which could be used to lift the heavy burdens of hunger and poverty that keep masses of men in bondage to ignorance and fear. Toward this peaceful development of nuclear power, we all have a high obligation to work with ingenuity and purpose.



This filter measures down time IN MINUTES — NOT HOURS!

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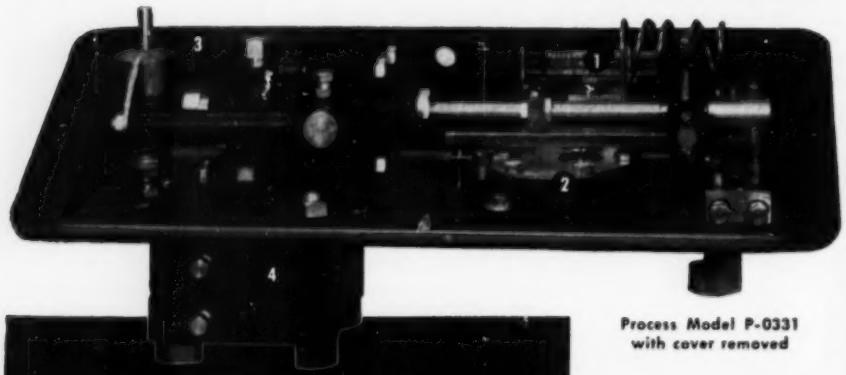
PROCESS CHANGES CAN'T OBSOLETE THIS TRANSMITTER . . .

❶ 10-1 RANGE CHANGE —NO CHANGE OF PARTS

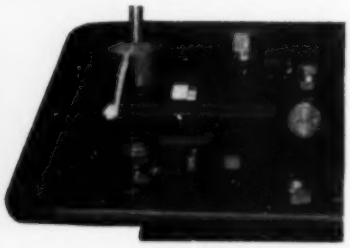
Double weighbeam construction on many models permits range changes as much as 10-1, just by turning a set of locking nuts to change a fulcrum point.

❷ ADDITIONAL 16-1 RANGE CHANGE—STILL NO PARTS CHANGE

Range may be changed on all models by loosening retaining bolts and sliding the reaction chamber to a new leverage position. Reaction area may be changed for further range change.



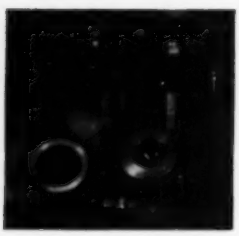
Process Model P-0331 with cover removed



❸ SUPPRESS, COMPOUND OR REVERSE RANGES

Balancing spring, installed to exert either an upward or downward force on transmitter weighbeam, quickly converts transmitter for range suppressions up to 80% of total range, for reversed ranges or for compound ranges where pressure fluctuates above and below atmospheric pressure.

REPUBLIC PNEUMATIC TRANSMITTER *with* EASY RANGE CHANGE



❹ MAJOR RANGE CHANGES

Range change plates may be easily inserted or removed from measuring chamber to change the effective diaphragm area for major range changes. Similar plates may be used also in the reaction chamber for further range change.

Here's the pneumatic transmitter for measuring differential, flow, pressure or level that saves you time and money when operating conditions are not definitely known or processes are likely to be changed. Extreme flexibility of design lets you adapt the same transmitter chassis for almost any range of measurements—often without any change of parts.

Process Model pictured above has a differential range of 0-12″ H_2O minimum and 0-880″ H_2O maximum at operating pressures to 1500 psig. Other models are available for differential ranges as low as 0-0.6 H_2O or as high as 0-750 psi.

Transmitters may be constructed of special materials to handle almost all types of corrosive fluids. Ruggedly built, they give long service out-of-doors. Accuracy is guaranteed at ½% of full range on standard models.

Republic transmitters are used in process, chemical and petroleum plants all over the country. Investigate their advantages for your plant.

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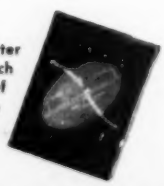
Get the full story about Republic transmitter flexibility. Send for free Data Book which gives all the facts about complete line of Republic transmitters, including Square Root Extracting and Pneumatic Electric models.



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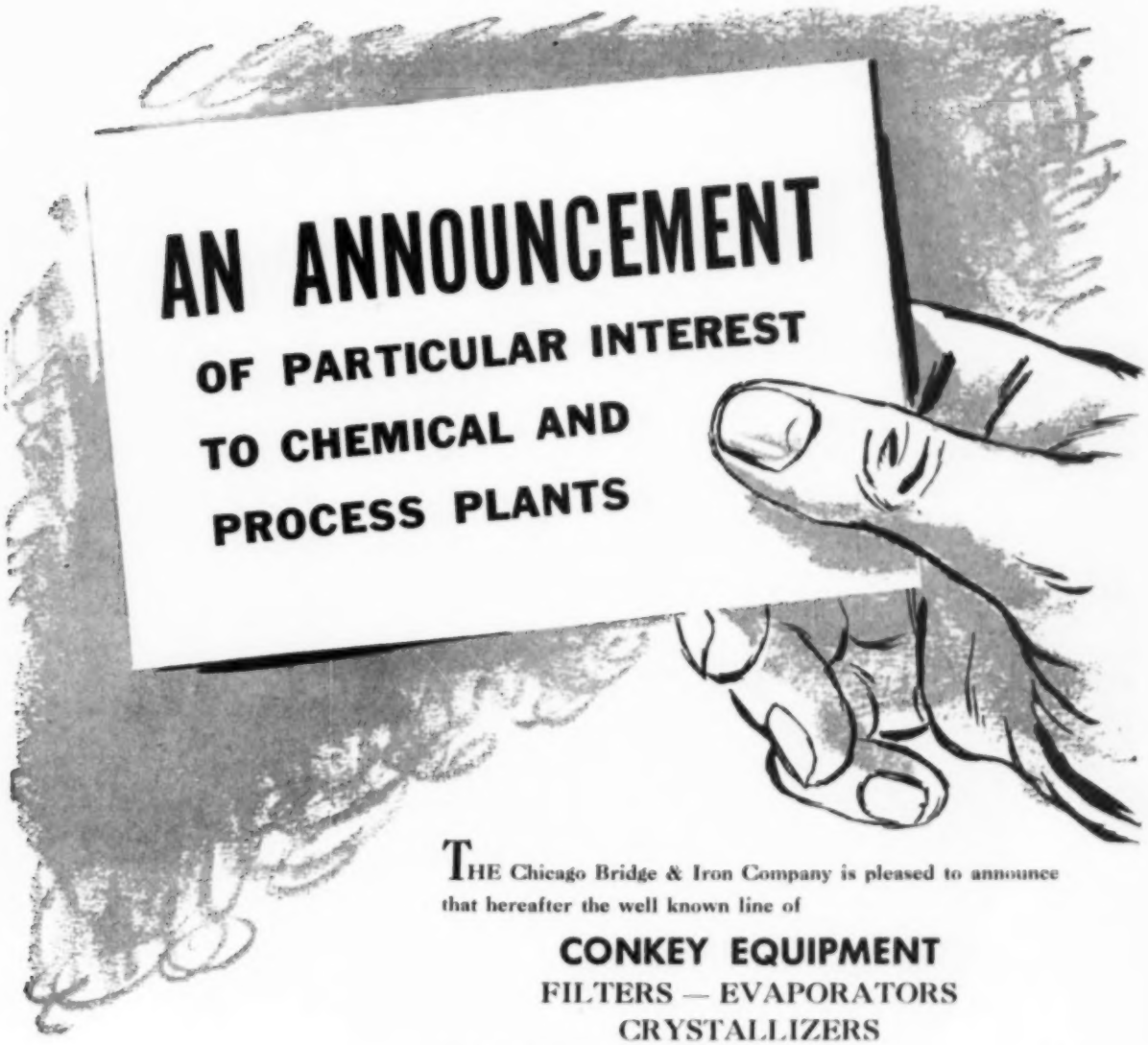

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Cleveland 15	2232 Midland Bldg.	Salt Lake City 4,	860 West 17th South St.
Detroit 26	1546 Lafayette Bldg.	San Francisco 4	1536—200 Bush St.
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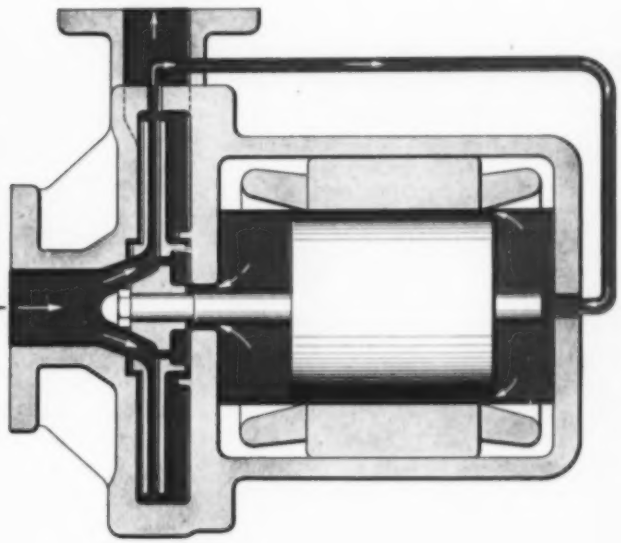

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Write at once for more data on this "years-ahead" centrifugal pump.

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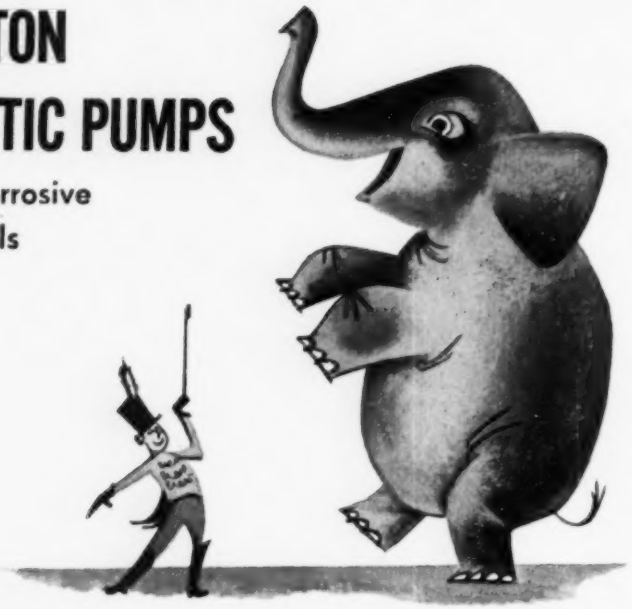

Flex-i-liner **PUMPS** are becoming industry's standard for those difficult to handle corrosive solutions and abrasive slurries, such as HCL, HF, NaOH, H_2SO_4, distilled H_2O, $FeCl_3$, HCOOH, and $Al_2(SO4)_3$, because their unique design eliminates stuffing boxes, shaft seals, gaskets and check valves.

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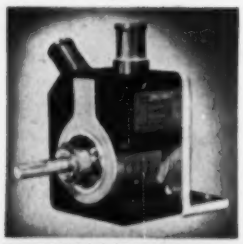
Flex-i-liner
Plastic Pump



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MARGINAL NOTES

(Continued from page 52)

medical field Marcus D. Kogel threw the weight of the problem to the recruitment and training of supporting personnel, but the working group of sixteen showed no inclination to oversimplify the situation and debated the entire structure of the medical profession, its facilities, and support.

Henry Chauncey sounded a dismal note regarding teaching, which seems to draw from the lower half of the college population as measured by intelligence tests, and which is handicapped by low prestige, low salaries, poor working conditions, and limited promotion possibilities. Although supply was recognized as a crucial element in the present situation, the need to make the good teachers better by means of technological aids was a major topic of discussion. Despite the attention given to the training and utilization of subprofessional personnel in engineering and medicine, as well as to the organization of the educational system, the small amount of space devoted to the potential of the subprofessional aide in teaching suggests that the subject did not receive all the consideration it merits.

Eli Ginzberg's summary of the six major approaches to better utilization of scientific and technological manpower gave point to Kenneth Boulding's keynote talk stressing the need not for manpower but for men, whether to train, to plan, to lead, or to do. Technological or labor-saving aids are useful only in the hands of men competent to use them.

This book should leave the reader with the uncomfortable but salutary feeling that there is not profit in looking for panaceas or miracles that will help make effective use of brainpower. Between the lines one reads the simple fact that by the judicious application of what is already known, something much better can be done than is now being done.

Books Received

A French-English Dictionary for Chemists, 2nd ed., Austin M. Patterson. John Wiley & Sons, Inc., New York (1954), xiv + 476 pp. $6.50.

Ferrous Process Metallurgy, John L. Bray. John Wiley & Sons, Inc., New York (1954), viii + 414 pp. $6.50.

Organic Peroxides, Their Chemistry, Decomposition, and Role in Polymerization, Arthur V. Tobolsky and Robert B. Mesrobian. Interscience Publishers, Inc., New York (1954), x + 197 pp. $5.75.

(More Marginal Notes on page 62)

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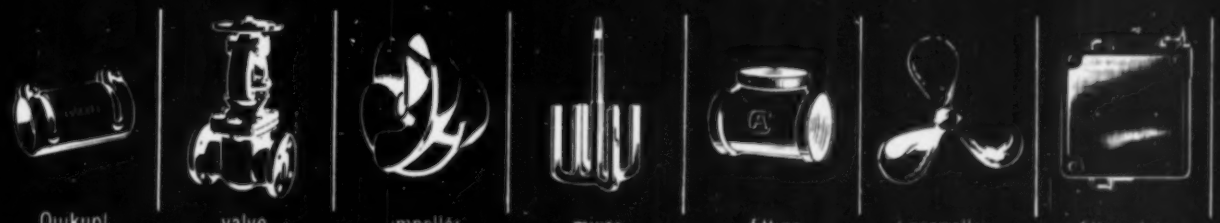

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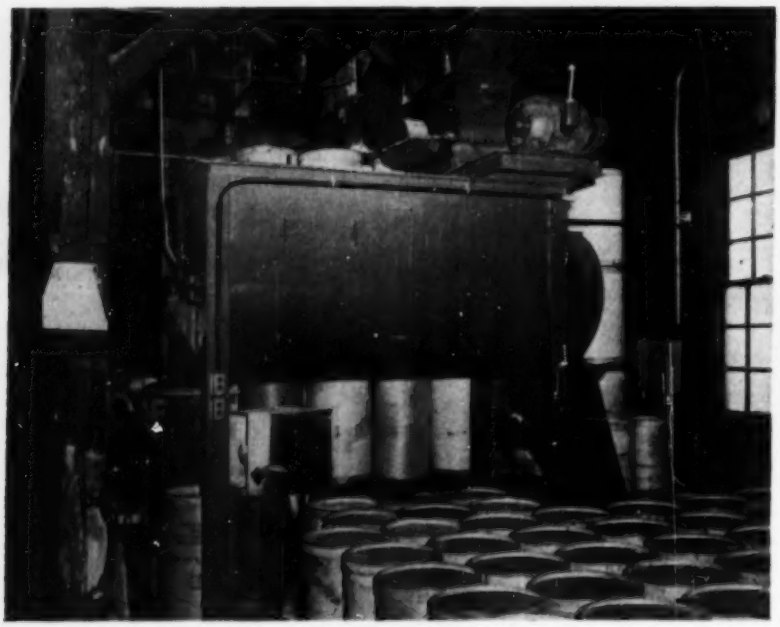

A manufacturer of cyanide and chloride salts, and other chemicals used in heat treating, carbonizing, and stripping metals wanted to step up production. Paul O. Abbé engineers designed for them a special blade arrangement which has speeded up the mixing operation.

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Result? The Paul O. Abbé Mixers, ranging in capacity from 1000 to 2000 pounds are meeting quantity and quality requirements, and are showing unusually low costs for maintenance and operation.

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PAUL O. ABBÉ

271 CENTER AVENUE LITTLE FALLS, NEW JERSEY

MARGINAL NOTES

(Continued from page 60)

Toxic Substances and Industrial Health

Toxic Solvents. Ethel Browning. Edward Arnold & Co., London. Distributed by St. Martin's Press, 103 Park Ave., New York (1953), viii + 168 pp. $4.00.

Reviewed by Fred Lorentz, Safety Process Engineer, Hoffmann-La Roche, Inc., Nutley, N. J.

How toxic are the solvents I plan to use in this new process? Just what physiological effect do they have on persons exposed to the vapors? What practical protective measures can be taken to safeguard the health of the worker? These questions repeatedly arise in the minds of responsible technical supervisors and research workers active in the complex operations of today's chemical industry.

Dr. Ethel Browning, a medical expert in the field of industrial health in Great Britain, has succeeded in presenting the properties of all major solvents in a well-organized manner in this new book.

The first chapter describes, generally, the physical and chemical characteristics of organic solvents which have a bearing on their possible toxic action.

The second chapter deals with the physiological effects solvents have on the living organism, particularly the human system. These two chapters establish the basis for describing the particular properties of the individual solvents contained in the remainder of the book.

Dr. Browning intended this book to be a practical reference on the subject of toxic solvents. In order to make it easy for the reader to glean the information he is seeking from the text, she has used the same outline of presentation for each compound, i.e., a brief description, including chemical structure, physical properties, flammability, industrial uses, acute toxicity, chronic toxicity, recommended treatment, and maximum allowable concentration of vapors in the atmosphere which is safe to work in daily. Another convenient device employed in this book is the grouping of the compounds into related chemical families. This makes it possible for the reader to infer the probable physiological effects of compounds not directly covered in the book by comparing them with compounds to which there is homologous relation.

The final chapter of the book outlines practical precautions which can be taken to control safely the health hazards of solvents encountered in industry.

This reviewer recommends the book as an *excellent* reference to be added to the intimate library of anyone engaged in chemical research, industrial chemistry, or industrial health. Within the brief span of 168 pp., Dr. Browning has been able to present a vast amount of pertinent, practical information on the toxic properties of a large variety of solvents in a highly usable form.

And What Moments!

Nuclear Moments, Norman F. Ramsey. John Wiley & Sons, Inc., New York (1953), 169 pp. $5.00.

Reviewed by H. G. Drickamer, Professor Chemical Engineering, University of Illinois, Urbana, Ill.

This book is divided roughly into three sections: (1) the theory of nuclear moments, (2) applications in physics, and (3) applications in chemistry.

The theoretical section is clearly and logically written, but requires some background in electromagnetic theory beyond that obtained in sophomore physics. However, many Ph.D. engineers should be able to follow it with a little effort.

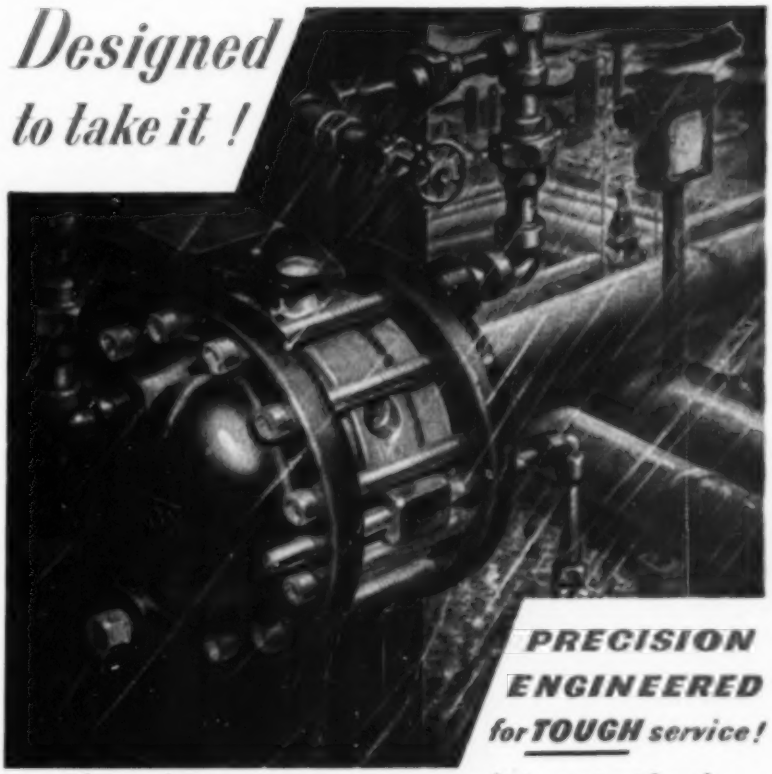
The largest section of the book is devoted to applications of the theory in physics, and particularly to molecular ray work, which is Dr. Ramsey's field. Though it is clearly written, it does not contain much of interest to engineers.

The section on application in chemistry appears to have been appended to the earlier, more unified treatment and is not so complete as the rest. It would seem that the nuclear magnetic moments may provide a useful analytical tool in certain mixtures supplementing the more common infrared and ultraviolet spectrograph. It is useful also for studies in molecular structure in connection with reaction kinetics, and for certain types of diffusion measurements.

At present the engineering applications of nuclear moments are rather remote, but several possibilities present themselves at the research level. This work is a well-written examination of the field and would be of more potential use to chemical engineers if it leaned more heavily on chemical applications.

1953 Annual Review of the Paint Industry. Compiled and edited by G. S. Cook. Paint and Varnish Production, Powell Magazines, Inc., New York (1954), 228 pp. $3.50.

Available in one volume, this review is a complete digest of the technical and commercial developments in all phases of the paint industry during the past year. Production techniques and test methods are covered. An index gives reference sources plus subject and author listings.



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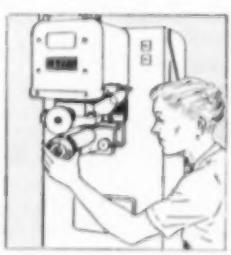

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A New Jersey Survey

Donald D. MacLaren

Standard Oil Development Co., Linden, N. J.

If membership in a local section grows, how can attendance at meetings decrease? This question perplexed the officers of the New Jersey Section and especially Donald D. MacLaren, secretary, who did considerable spade work to find out reasons. In the accompanying article Mr. MacLaren discusses three factors that influence meeting attendance. All local section heads will benefit from a reading of this survey.

What makes Johnny run—to local section meetings that is? Members of the New Jersey Section have been trying to find out. Specifically, we wanted to know why the average attendance at meetings has varied so much from year to year, and why the number of people attending meetings has dropped though membership has increased.

The New Jersey Section was formed five years ago. Disregarding its first year because of growing pains, it has chalked up twenty-eight meetings to help relate why Johnny runs. Statisticians will not be awed by the amount of data. But the story that these three and one-half years tell is an interesting one.

Off hand, there would seem to be three major factors affecting meeting attendance—namely, the number of section members, the meeting place, and the program.

Table 1.

Year	1952-53	1951-52	1950-51
Section membership	715	672	595
Average attendance	131	228	176

One would certainly expect that the larger an organization, the larger the attendance at its meetings. This is not the case as far as the New Jersey Section is concerned. The membership of the section has steadily grown from about 500 the first year to more than 700 in 1953. Yet, as shown in Table 1, meeting attendance last year was the poorest since the section's founding.

This is certainly a curious situation. If nothing else, it reflects credit on our Membership Committee and its selling abilities.

Because of the success of the Membership Committee, its setup is worth mentioning in passing. Membership applications are sent out in May of each year to all former section members and A.I.Ch.E. members in the area. This mailing, together with the membership desk at the Annual Symposium in May, accounts for about 200 to 250 of the membership. The rest are signed up by the Membership Committee partly at meetings, but largely at the plants in the section area. There is a member of the Membership Committee in each of the major industrial plants. It is his job, either personally, or by subcommittee, to contact all eligible engineers in his plant. As a result, 25% or more of the chemical engineers in these companies join the section. In this regard one man seems able to contact about ten to fifteen others effectively, that is, to sign up 75% or more of those he sees. The more he must contact over this number, the poorer his efficiency. The size of the New Jersey Section attests to the success of this system.

Attendance and Specific Locality

The New Jersey Section serves a wide area; all of northern and central Jersey are named in its Constitution. Because some people living on the fringe of this area may have to travel 20 to 25 miles to a meeting, an effort is made to move the meeting place around. Since certain towns are easier to reach, or are nearer the concentration of membership, attendance might well reflect these shifts in meeting place.

For those who are not familiar with New Jersey, a brief lesson in geography is in order. As shown in Table 2, the meetings have been concentrated in six areas. In general all of the meeting places are located in the north central section of the state—Bound Brook, Newark, and New Brunswick lie near the periphery of the area, and the others are nearer the center.

Meeting place appears to have little effect on attendance. Little difference between the various locations is shown in Table 2. Plainfield, which is located in the center of the area, may have a slight edge. Newark and New Brunswick, which are on the fringe of the area, may be somewhat low. Both these locations, however, are plagued with a shortage of parking space. This, rather than location, may account for the somewhat poorer attendance.

One pertinent question here is whether the majority of those attending a meeting come from the area where it is held. One might expect this to be true or at least partially so. But, since the average yearly attendance has varied twofold, it is reasonable to assume that some members do come quite a way to attend certain meetings.

What then, makes Johnny run? Since membership and meeting place appear relatively unimportant, the program for the meeting must be the crux of the matter. In the sense that it provides a clue, it is fortunate that attendance has varied over the past three and one-half years. This wide variation furnishes a good idea of just what type of program the section wants.

Table 3 lists the kinds of meeting held in the past few years and the attendance figures for each type. The meetings have been broken down into four more or less arbitrary types—Strictly Tech-

(*Continued on page 72*)

Table 2.—Effect of Meeting Place on Attendance

Per Cent of Average Attendance for the Year

Area	1953-54	1952-53	1951-52	1950-51	Avg.	Total Number of Meetings
Plainfield	104	...	165	120	130	3
Bound Brook	103	130	107	94	109	8
Elizabeth	...	115	85	107	102	4
Summit	96	72	102	108	95	5
Newark	96	...	59	97	84	3
New Brunswick	...	78	72	74	75	5

STAYNEW FILTERS' DOUBLE ACTION

Guards Against Water, Oil and Pipe Scale

MECHANICAL SEPARATION

1. Deflector cup directs flow of air or gas together with water, oil and dirt to the walls of the housing and then downward at high velocity into the base where liquid and heavier dirt particles are deposited.

FILTRATION

2. Air or gas, having been mechanically cleaned, rises at low velocity through the Radial Finned Filtering element or insert which removes the lighter air-borne material.

MODEL CPH
PIPE LINE FILTER

This exclusive Double-Action principle of Staynew Pipe Line Filters assures sustained, trouble-free operation. Inexpensive, quickly installed and easily maintained, these filters keep air operated or controlled equipment free from pipe scale, dust, dirt, and condensate. Wherever you require air and other gases *clean* and *dry*—demand and get—Staynew Pipe Line Filters.

Write today for complete Staynew Pipe Line Filter Bulletin B-1A.

Representatives in Principal Cities

DOLLINGER PROTECTOMOTOR STAYNEW FILTERS

DOLLINGER CORPORATION
79 Centre Pk., Rochester 3, N. Y.

ALL TYPES OF FILTERS FOR EVERY INDUSTRIAL NEED

Carpenter **Stainless Tubing...**

doesn't cost ...IT PAYS

... in cost-cutting corrosion resistance, time-saving fabrication, and extended service life.

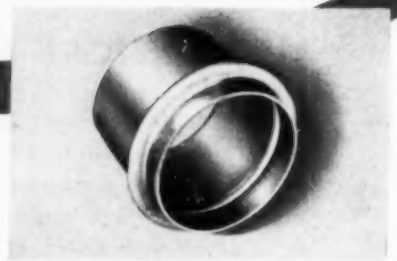
It's this way. There's a difference in stainless tubing quality and uniformity—and Carpenter makes it. Pictured here are three random examples. Hundreds more are on file from process equipment fabricators and chemical plant engineers citing how the difference in Carpenter Stainless Tubing pays off in easier fabrication, lower production and maintenance costs, and more freedom from costly corrosion troubles and equipment "down-time".

In short, you get all-around stainless tubing satisfaction when you give Carpenter Stainless Tubing the job of handling corrosive materials in your plant. You can count on your nearby Carpenter Distributor or Branch Office for prompt service on your requirements and experienced technical help in selecting and fabricating your tubing.

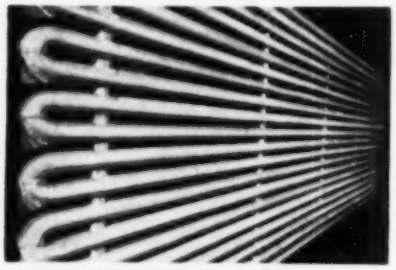
The Carpenter Steel Company, Alloy Tube Division, Union, N. J.

Branch Offices: Atlanta Chicago Pittsburgh Houston Newark San Francisco

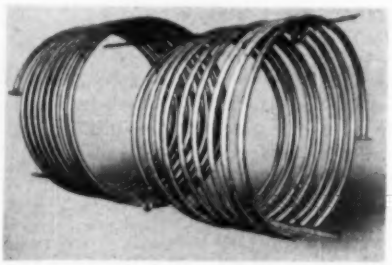
Export Dept.: The Carpenter Steel Co., Port Washington, N. Y. "CARSTEELCO"



FOR EQUIPMENT PARTS—ability of Carpenter Stainless Tubing to "take" severe fabrication due to its uniformity and ductility saved fabricator of this bubble cap 10c a piece and enabled him to get longer production runs.



FOR PROCESSING EQUIPMENT—ten cooling coils like this were made from Carpenter Stainless Tubing at a saving in material of about $1000 because uniform walls permitted using a lighter gauge.



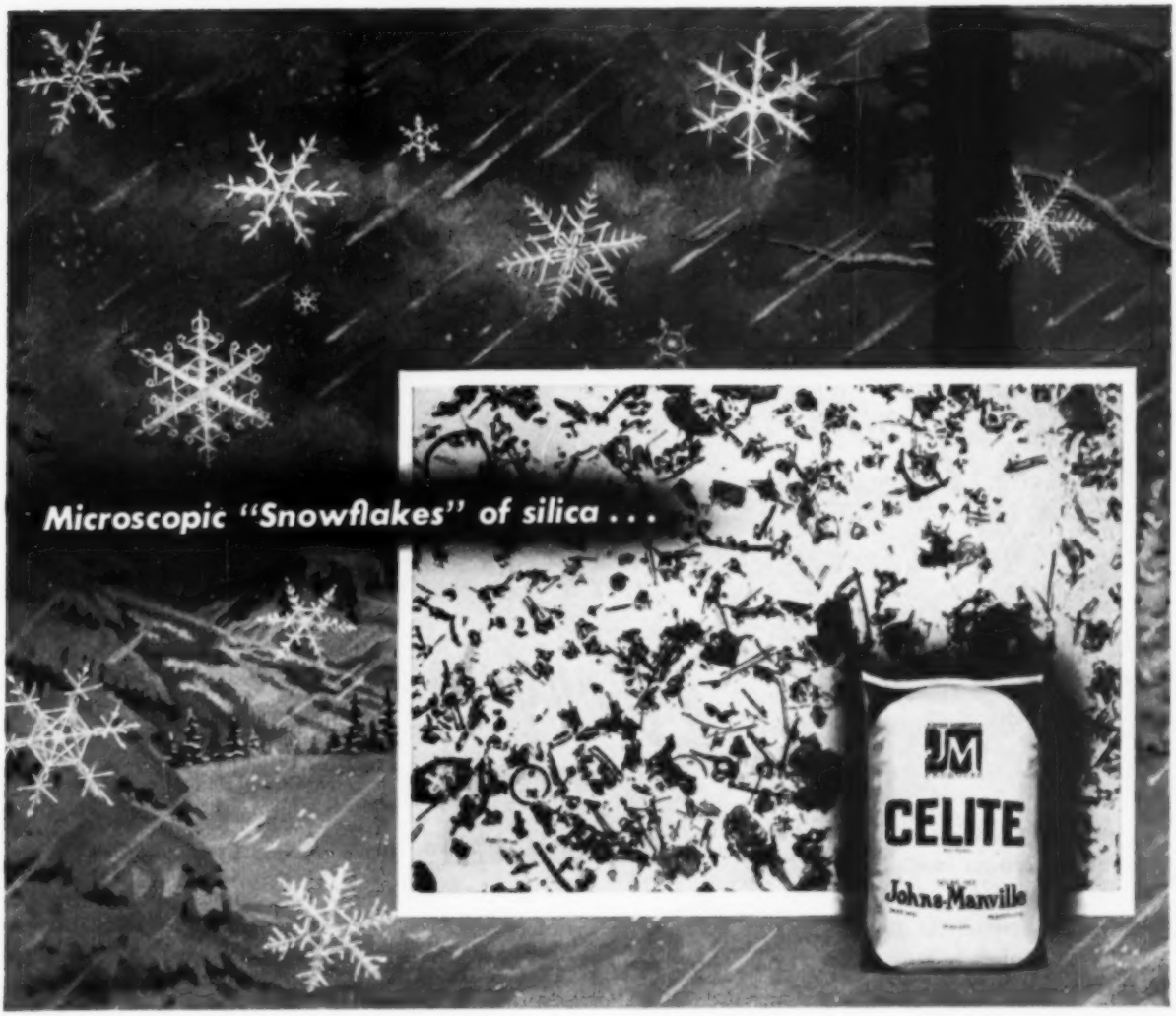
FOR SUPER CORROSION RESISTANCE—coil life in a hydrolysis tank was more than doubled by switching from lead to Carpenter Stainless No. 20.

Carpenter

STAINLESS TUBING & PIPE

Analysis · Tolerance · Finish

· guaranteed on every shipment



Celite's diatomite structure steps up performance

in paints—plastics—polishes . . . hundreds of other products

MICROSCOPIC PARTICLES of Celite* do a man-size job of stepping up performance for many of America's leading products. Here is how the unique structure of Celite Diatomite Powders may add more beauty, longer life, greater efficiency to *your* products, too.

For example, the spiny, irregularly shaped particles contribute surface characteristics which make them the outstanding flatting agent in paints. Again, because of their structure, Celite particles are widely used as a mild, non-scratching abrasive in finest quality auto, silver and glass polishes. Or consider molded plastics, where the strength and durability of Celite particles add life and beauty to surface finish.

Moreover, Celite particles in mass have great bulk per unit weight, so they are invaluable for extending, dispersing or fluffing up dry powders. They have high absorptive capacity, too, so they keep powders free-flowing, they serve as a medium for shipping or storing liquids in a dry form.

Which of the many Celite advantages can you use to build product performance or cut production costs? A Johns-Manville Celite Engineer will gladly discuss your problem, without obligation. For his services or more information, simply write Johns-Manville, Box 60, New York 16, N. Y. In Canada, 199 Bay Street, Toronto 1, Ontario.

*Celite is Johns-Manville's registered Trade Mark for its diatomaceous silica products.

JM PRODUCTS **Johns-Manville CELITE** INDUSTRY'S MOST VERSATILE MINERAL FILLER

DURASPUN SCREW CONVEYOR

. . . because it's properly alloyed

. . . because it's centrifugally cast

Centrifugal Castings can be more than conventional piping. Almost any roughly cylindrical shape can be cast centrifugally provided a straight hole through the center is allowable. In the casting machine the molten metal is thrown outward, making it impractical to cast solid.

This Duraspun Screw Conveyor is typical of the unusual castings produced in our centrifugal casting department. On straight piping, our machines are capable of turning out pipes ranging in 2½" to 31" OD and, according to diameter, up to 15' long.

If you are interested in superior castings — more uniform, denser and pocket-free castings — order centrifugal castings. Write us about your requirements and we'll recommend the proper alloying elements to meet your corrosive, high temperature, abrasive conditions.

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NEWS

(Continued from page 47)

FIRST FULL-SCALE NUCLEAR POWER PLANT

One of the latest developments in the electric industry's nuclear power program is the decision by the Duquesne Light Co., Pittsburgh, to construct and operate under contract to the Atomic Energy Commission the nation's first full-scale central-station nuclear power plant, the nuclear reactor for which is being designed and built by the Westinghouse Electric Co.

Duquesne will provide a site 25 miles northwest of Pittsburgh for the 60,000-kw. plant, build the electric generating portion, and operate the plant at no cost to the government. It will also assume $5 million of the cost of research, development, and construction of the pressurized water reactor and pay the A.E.C. for steam used in the turbines.

NEW CANADIAN CO. BUILDS REFINERY

Construction of a $20 million refinery for a new Canadian oil company, Canadian Petrofina, Ltd., has been announced for location near Montreal. Much of the new plant will be of integrated combination design, which will eliminate considerable intermediate storage. Designed to handle both Middle East and Venezuelan crudes, the plant will include a 20,000-bbl./day topping unit, vacuum-flashing capacity of about 10,000 bbl./day, a 4,000-bbl./day visbreaking unit, a 3,600-bbl./day catalytic reforming unit, catalytic polymerization and alkylation units with feed desulfurization facilities, a 2,500-bbl./day distillate-treating unit, and a 6,500-bbl./day gasoline-treating unit. The plant will be erected by Canadian Kellogg Co., Ltd., a wholly owned subsidiary of Kellogg.

A.S.T.M. MEETING IN JUNE

The fifty-seventh annual meeting of the American Society for Testing Materials, to be held in Chicago from June 13 to 18, will feature an exhibit of testing and scientific apparatus and laboratory supplies, at the Hotel Sherman. The meeting itself will include thirty-six technical sessions. Among the symposium topics will be coal sampling, temperature stability of electrical insulating materials, odor, permeability of soils, effect of cyclic heating and stressing on metals at elevated temperatures. A round-table discussion on the significance of specifications will be held during the meeting by representatives of industry and government.

(More News on page 70)

"NATIONAL"

Conveyor Type DRYERS

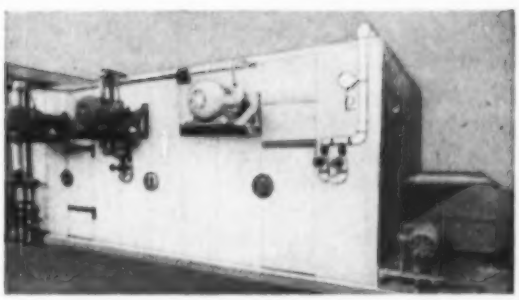
FEATURING... *Increased Drying Capacity Through an Improved System of Air Distribution*

The new records being established by **"NATIONAL"** Conveyor Type Dryers for drying speed and quality, in some of the largest Chemical plants, are the result of a unique air distribution system which assures an unequalled measure of uniformity in the volume and temperature of the air at the apron. Graphs prove this level of maximum effectiveness of the drying medium to be virtually *constant*, which means less time required for thorough drying, and therefore, faster passage of the loaded conveyor through the machine.

Other features of **"NATIONAL"** Conveyor Type Dryers include flexibility in operation, ease of maintenance, and unit construction for economical future expansion. *Write for complete information.*

• • •

OTHER "NATIONAL" EQUIPMENT FOR THE CHEMICAL INDUSTRY includes Batch and Tunnel Type Truck Dryers; Cabinet Type Shelf or Tray Dryers; Extruders and Test Dryers. All are engineered to assure unequalled drying uniformity and speed under critical drying conditions, to provide the lowest possible cost per unit of product dried.



ANY REQUIRED TYPE AND SIZE

"NATIONAL" Conveyor Dryers may be of single or multiple apron construction, with perforated, solid belt, wire mesh or slat aprons. They can readily be designed for continuous, production-line connection to **"NATIONAL"** extruders, automatic feeders or other special handling equipment. Sizes range from small compact, 8' × 12' units, to multiple-unit tunnel constructions several hundred feet long.

THE NATIONAL DRYING MACHINERY CO.
LEHIGH AVENUE and HANCOCK STREET
PHILADELPHIA 33, PENNA.

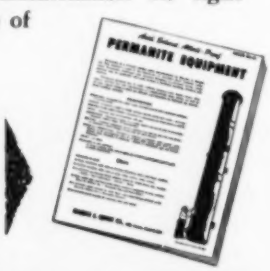
FROM VALVES TO TOWERS
This new Permanite Diaphragm Valve embodies excellent resistance to corrosives, acids, alkalies, solvents, abrasion and erosion.
WITH
PERMANITE

Permanite is a thermosetting furfuryl alcohol resin, which can be fabricated into many types of corrosive handling equipment. It can be supplied in almost any shape from valves to large towers. Permanite Equipment is corrosion-proof throughout its entire body. It will handle most acids including HF, HCl, as well as oils, alkalies and organic solvents at sustained temperatures in excess of 240°F. It is lightweight but very dense, strong, and shock resistant.

Permanite, reinforced with chemical fiberglass, is fabricated into complete functional units such as tanks, absorbers, towers and fume washers. It is also available in lightweight pipe and fume ducts. Permanite can be molded into a variety of finished units such as valve bodies, trays and bubble caps.

Permanite equipment requires little maintenance. Its light weight provides an added advantage — ease of handling and installing.

Knight engineers are glad to cooperate in designing Permanite equipment to specification. Send for illustrated Bulletin No. 6 — Permanite Equipment, Bulletin No. 1 — Permanite Pipe and Ductwork or Bulletin No. 15 — Permanite Diaphragm Valves and learn how Permanite can help solve your corrosion problems.



Maurice A. Knight 705 Kelly Ave., Akron 6, Ohio
Acid and Alkali-proof Chemical Equipment

TECHNICAL PROGRAM

(*Continued from page 41*)

APPRAISAL OF REACTOR SYSTEMS FOR CENTRAL STATION POWER PLANTS, T. Stern, Nuclear Power Project, Foster Wheeler Corp., New York.

LIQUID METAL FUEL REACTOR SYSTEMS FOR POWER, C. Williams and F. T. Miles, Brookhaven National Laboratory, Upton, N. Y.

ECONOMIC POWER FROM FAST REACTORS, J. V. Dunworth and C. A. Rennie, Atomic Energy Research Establishment, Harwell, England.

OPTIMIZING AND COMPARING REACTOR DESIGNS, F. T. Miles and I. Kaplan, Brookhaven National Laboratory, Upton, N. Y.

TECHNICAL SESSION No. 19

(Joint Meeting with Association for Computing Machinery)

Automatic Computation in Nuclear Engineering

Chairman—Alston S. Householder

HIGH SPEED REACTOR CALCULATIONS, Ward C. Sangren, Oak Ridge National Laboratory, Oak Ridge, Tenn.

RATES OF CONVERGENCE IN NUMERICAL SOLUTION OF THE DIFFUSION EQUATION, R. H. Stark and Glenn Roe, General Electric Co., Knolls Atomic Power Laboratory, Schenectady, N. Y.

DIGITAL METHODS IN NUCLEAR REACTOR SPACE SIMULATION, W. F. Bauer, J. W. Carr, R. Dames, G. Graves, Willow Run Research Center of the University of Michigan.

THE GENERALIZED ONE-DIMENSIONAL SPACE SIMULATOR, R. R. Schiff, Westinghouse Electric Corp., Atomic Power Division, Pittsburgh, Pa.

THE WESTINGHOUSE ANALOG COMPUTER FOR REACTOR SPECIAL FLUX DISTRIBUTION, Frank Engel, Westinghouse Corp., Atomic Power Division, Pittsburgh, Pa.

ELECTRONIC SIMULATION OF NUCLEAR REACTORS, K. A. Fischbeck, Bendix Aircraft Co. Research Laboratories, Detroit, Mich.

PUBLICATION OF PAPERS ON INSTRUMENTATION

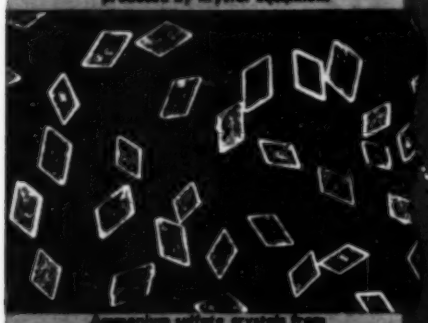
Proceedings of the Symposium on Instrumentation for Industrial Hygiene at the University of Michigan from May 24 to 27, 1954, will be issued in two formats. There will be a complete compendium in one volume, of interest to libraries, research and industrial organizations, etc., and an eight-volume edition divided into the areas of instrumentation covered in the Symposium. Prices of the publication have not yet been determined. Further details may be secured from the Continued Education Service, 109 South Observatory Street, Ann Arbor, Mich.

LOUISIANA FIRM TAKES NEW NAME

A change in the corporate name of Universal Oil Products Company of Louisiana, located at Shreveport, has been announced by the parent company. The name Universal Polychem Company will be applied to the Louisiana company, and operations and policies will remain unchanged.

(*More News on page 87*)

Potassium carbonate crystals produced by Krystal Equipment



Ammonium sulfate crystals from technical grade acid

Potassium chloride crystals

Ammonium sulfate from by-product acid

Fluidized Crystal Suspension in

STRUTHERS WELLS

KRYSTAL

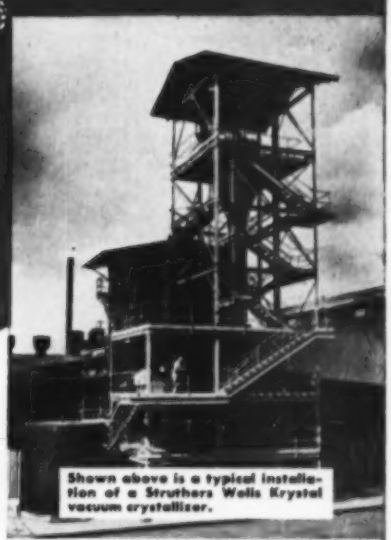
PATENTED

CRYSTALLIZATION EQUIPMENT

insures

1. Economical operation—Heating and cooling surfaces stay clean
2. Excellent steam economy
3. Product of high purity
4. Exceptionally uniform crystals
5. Controllable crystal size

Shop view of Krystal Crystallization Equipment. This unit is 30' 0" high and 11'3" in base diameter.



Shown above is a typical installation of a Struthers Wells Krystal vacuum crystallizer.

Krystal crystallization equipment provides efficient separation of crystals and mother liquor—reduces amount of wash water—eliminates dust losses—reduces caking of material in storage and produces free flowing crystals of superior appearance.

Struthers Wells

STRUTHERS WELLS CORPORATION WARREN, PA.

Plants at WARREN, PA. and TITUSVILLE, PA.

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YOUR BUSINESS CHANGED ON JANUARY 21, 1954

On that morning the atomic-powered submarine USS Nautilus slid down the ways confirming the first large-scale application of controlled nuclear power. The basic technological advances that made this feat possible are today opening new frontiers for American industry. Have you opened your door to these advances in your business?

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Nuclear Development Associates, Inc., America's senior nuclear engineering firm, offers to industry specialized research, development, engineering and design services based upon these advanced technologies. Our services for government and industry include:

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- industrial uses of radiation
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White Plains 8-5800

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Organization

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C-1

A NEW JERSEY SURVEY

(Continued from page 64)

Table 3.—Effect of Type of Meeting on Attendance

Average Attendance for the Year (No. of Meetings)

Type of Meeting	1953-54	1952-53	1951-52	1950-51	Avg.	Total Number of Meetings
Popular Science	125(1)	..,(0)	280(3)	180(2½)	195	6½
Professional	.....	...(0)	197(3)	186(1)	191	4
Strictly Technical	131(3)	143(7)	197(2)	181(3½)	163	15½
Current Events	.....	55(1)	...(0)	131(1)	93	2
Average Attendance	130	131	228	176		

nical, Popular Science, Professional, and Current Events. Strictly Technical refers to meetings dealing with engineering theory or practice and is not necessarily limited to chemical engineering. Popular Science deals, as the name implies, with currently interesting fields of allied science such as astronomy, space travel, atomic energy, etc. Professional means subjects relating to the engineer's professional responsibility and status. Current Events covers topics of national and international interest of a strictly non-technical nature.

As noted in Table 3, popular science and professional programs head the list. However, technical programs are almost as popular. In this regard general over-all appeal of the technical subject seems just as important as the name of the speaker. Current events rate a poor fourth. But so few meetings of this type have been held, the data may not be significant.

What the data seem to indicate is that a varied program is preferred. For example, 1951-52, the best year, saw only two technical programs, the others being split between Popular Science and Professional. In 1950-51, the next best year, the program was a little more on the technical side, but still varied. Last year, the poorest, to date, was almost all technical. Variety still seems to be the spice of life!

An interesting fact regarding the first two or three meetings of the year was noted in reviewing the data. There is an amazingly good correlation between the attendance at the first two meetings and for the rest of the year. This is shown in Table 4. First impressions are apparently lasting! A special effort to have as good a program as possible for the first two or three meetings seems in order.

Variety of Program—A Factor

A review of the past meetings indicates that the program makes Johnny run. Variety in program seems to be most important. This poses a problem. If the varied program indicated is provided, only two, or possibly three, technical meetings will be held a year. Since the section is part and parcel of a technical society—A.I.Ch.E.—is this right?

The answer would seem to lie in what the membership really wants and expects from the meetings. If it be technical information, a varied program is the wrong tack. On the other hand, if it be the cultivation of professional contacts in the area, the program, which will net the best attendance, is the right one.

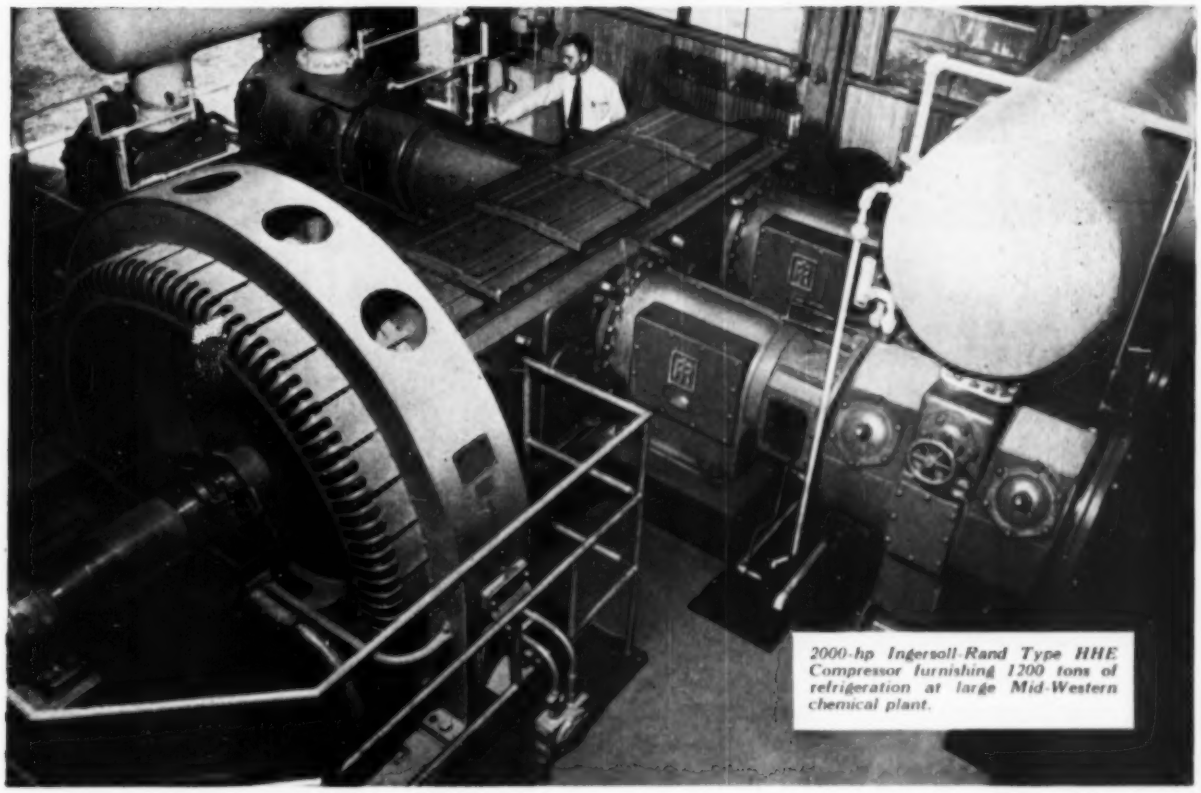
This question must be answered for the benefit of our members and the national society too. To obtain the answer the section plans to use a questionnaire. It will be distributed in various plants in the area by the Membership Committee. It will cover all the points discussed here—type of program and number per year, meeting place and date, reasons for attending or not attending meetings, and reasons for belonging to or not rejoining the section. By collating all the data received and then planning the meetings to coincide as far as possible with the expressed desires of the membership, the New Jersey Section hopes to serve adequately and well the chemical engineers in our area. Through the use of the questionnaire too, perhaps this section can help make Johnny really run in *all* 48 states!

Table 4.

Avg. Attendance Year	1953-54 to date	1952-53	1951-52	1950-51
First 2 meetings	130	130	285	175
For entire year	130	131	228	176

5 YEARS OF CONTINUOUS SERVICE

with practically **No Maintenance**



2000-hp Ingersoll-Rand Type HHE Compressor furnishing 1200 tons of refrigeration at large Mid-Western chemical plant.

2000-hp ammonia compressor gives outstanding performance at large chemical plant

Installed in 1949 this heavy-duty Ingersoll-Rand compressor has been in continuous service supplying 1200 tons of refrigeration for a large Mid-Western chemical plant. Driven by a 2000-hp synchronous motor, it compresses ammonia in two stages from 11 psig to 215 psig. During these five years' operation there has been practically no maintenance or replacement of parts.

Based on this outstanding performance record, the company has recently installed a 3000-hp air compressor of the same fundamental design, thus taking advantage of the interchangeability of most of the wearing parts. 1-50

If you have processes calling for compression or evacuation of air or gas you can surely benefit from Ingersoll-Rand's experience in designing and building the world's most complete line of reciprocating and centrifugal compressors. Your I-R engineer is well qualified to give you expert assistance, no matter what the gas, pressure, temperature or process.

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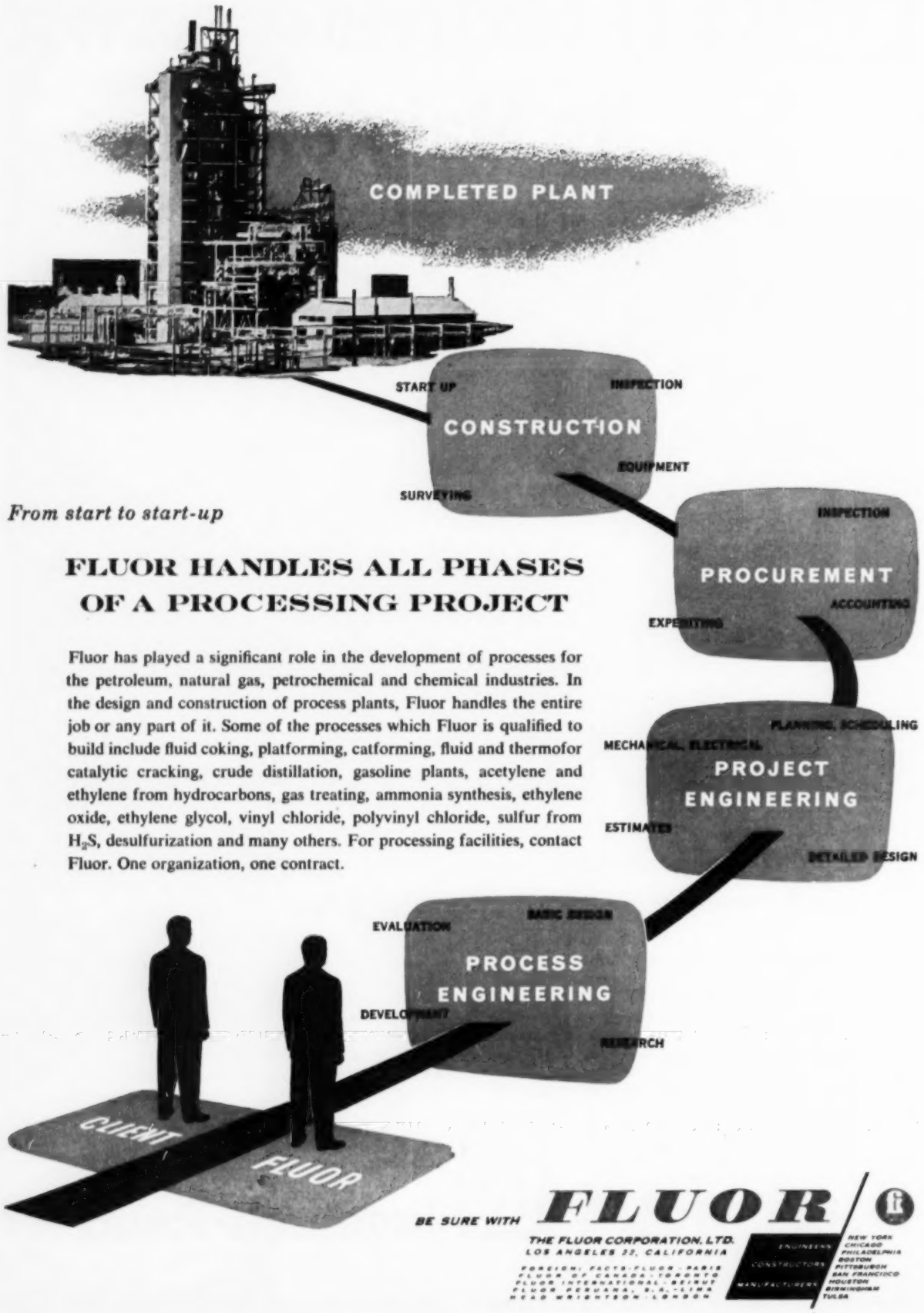
11 Broadway, New York 4, N. Y.

COMPRESSORS • AIR TOOLS • ROCK DRILLS • TURBO BLOWERS • CONDENSERS • CENTRIFUGAL PUMPS • DIESEL AND GAS ENGINES



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Fluor has played a significant role in the development of processes for the petroleum, natural gas, petrochemical and chemical industries. In the design and construction of process plants, Fluor handles the entire job or any part of it. Some of the processes which Fluor is qualified to build include fluid coking, platforming, catforming, fluid and thermofor catalytic cracking, crude distillation, gasoline plants, acetylene and ethylene from hydrocarbons, gas treating, ammonia synthesis, ethylene oxide, ethylene glycol, vinyl chloride, polyvinyl chloride, sulfur from H_2S, desulfurization and many others. For processing facilities, contact Fluor. One organization, one contract.

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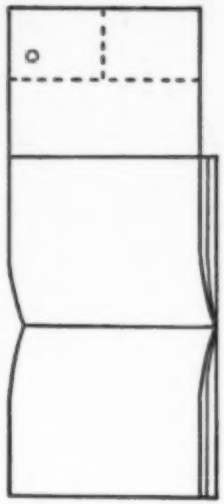
Just a moment is needed to learn how to use this insert. When looking through the front part of the magazine pull the folded portion of the insert out to the right, and the numbers on the post card are convenient for marking. THEN . . . .



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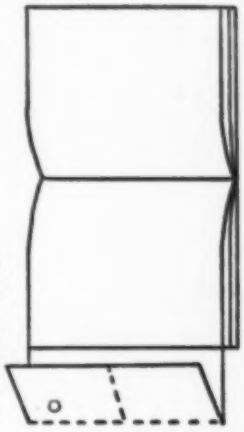

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Manufacture of ethylene oxide by direct oxidation now produced at 4 locations.
Carbide and Carbon Chemicals Co.

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All-metal construction. Four-point drive eliminates rods or flexible supports.
B. F. Gump Co.

4A **Chlorine Valves**
Now available with screwed ends and flanged ends. Designed for water-free chlorine gas or liquid up to 300° F. Sizes ½ to 2-inch.
Crane Co.

5A **Process Engineers**
Services for the atomic energy, chemical, petrochemical and oil refining industries.
Catalytic Construction Co.

6L **Glass Stirrers**
Complete range of standard taper joints and interchangeable spherical joints. Blades available in Teflon or glass.
Ace Glass, Inc.

7A **Custom Fabrications**
Specialized skills in working modern metals.
Nooter Corp.

8A **Plant Design and Construction**
Describes two current projects; catalytic polymerization, and secondary butyl alcohol synthesis.
Badger Mfg. Co.

9A **Valves**
Y-valves, angle valves, flush valves, safety valves, and plug cocks of porcelain.
Lapp Insulator Co., Inc.

10L **Plug valves**
Feature pressure seal packings and special plug adjusting nut. Also line blind valves.
Hamer Oil Tool Co.

11A **Designers, Engineers and Constructors**
Manufacturing plants for the petroleum and chemical industries.
The Lummus Co.

12A **Chemical Pumping**
Pumps with discharge pressures from 300 to 15,000 lb./sq.in.
The Aldrich Pump Co.

13A **Packless Expansion Joints**
Permits movement of a pipe line while keeping anchor loads at a minimum. Also slip joints.
American District Steam Co., Inc.

14L **Rupture Disc**
For low pressure applications in extreme corrosive conditions. Pressure ratings from 8 to 100 lbs.
Black, Sivalls & Bryson, Inc.

15A **High Vacuum Pumps**
Line of 13 single stage and compound vacuum pump models.
Kinney Mfg. Div., The New York Air Brake Co.

16A **Demisters**
To eliminate metal contamination due to liquid entrainment in vacuum towers. Stainless steel.
Otto H. York Co., Inc.

17A **Mikro Systems**
Grinding, blending, air conveying, dust collection unified in a single system.
Pulverizing Machinery Div., Metals Disintegrating Co., Inc.

18A **Synthetic Ethanol Plant**
Describes company's part in several special features of a synthesis plant.
The Vulcan Copper & Supply Co.

19A **Ratographic Totalizer**
Continual integration at rate of 24 times/min. 100 rev./min.—72 pole synchronous motor.
Fischer & Porter Co.

20A **Crystal Dehydration**
Dehydrators produce up to 8 tons/hr. of bulk crystals.
The Sharples Corp.

21A **Accelerators**
Radiation power available to industry for experimental and process work. Uses in plastics, radiography, oil industry described.
High Voltage Engineering Corp.

22A **Electrical Weighing System**
Measures batch ingredients automatically.
Minneapolis-Honeywell Regulator Co.

24A **Heat Transfer Medium**
Single vaporizer serves several consuming points with different temperatures at the desired degree.
The Dow Chemical Co.

25A **Pulsafeeder Pumps**
Non-metallic construction. Combination piston-diaphragm pump for controlled-volume pumping of fluids.
Lapp Insulator Co., Inc.

26A **Acheson Graphite Anodes**
Features installation in a new chlorine-caustic plant.
National Carbon Co.

27A **Rotocel Extractors**
Describes design, engineering and construction.
Blaw-Knox Co., Chemical Plants Div.

28L **Expansion Joints and Flexible Couplings.**
To protect piping. Made of Teflon.
United States Gasket Co.

29A **Catalysts**
Catalysts for a wide range of processing applications or to meet specifications.
The Girdler Co.

30A **Measurement of Dew Point**
Instruments to measure or control the humidity of air or process gases.
The Foxboro Co.

32L **Oil Reclaimer**
Equipment for reclaiming, filtering, purifying and refining oil.
The Hilliard Corp.

32R **Filter Papers**
Manufacture of filter papers for laboratory and industry. Booklet.
The Eaton-Dikeman Co.

33A **Graphite Anodes**
Graphite anodes for the electrolytic industry in making chlorine and caustic soda for antiknock compounds.
Great Lakes Carbon Corp., Electrode Div.

Chemical Engineering Progress

Numbers followed by letters indicate advertisements, the number corresponding to the page carrying the ad. This is for ease in making an inquiry as you read the advertisements. Letters indicate position—L, left; R, right; T, top; B, bottom; A indicates a full page; IFC, IBC, and OBC are cover advertisements.

Be sure to give name, address, position, etc.

Remember, the numbers on the upper portion of the card bring you data on only the bulletins, equipment, services, and chemicals reported in these information insert pages. The lower portion of the card is for the advertised products, and is keyed not only to advertising pages, but also to the memory-tickling list under the heading Products.

34A **"Corrosioneering"**
Discussess expert help in designing and fabricating process equipment.
The Pfaudler Co.

216A **Louisville Dryer**
Rotary coolers and rotary steam-tube dryers.
Louisville Drying Machinery Unit, General American Transportation Corp.

43A **Tygon Plastic**
Used in sheet form as a protective lining for tanks or gasketing in sealing operations. As a liquid Tygon serves as a paint and as a dip coating.
U. S. Stoneware Co.

44L **Lattice Braid Packing with Teflon**
For shaft and rod packing.
The Garlock Packing Co.

45A **Anti-Biotic Dryers**
Unit removes organic solvent from an anti-biotic. Also coolers, calciners, and kilns.
The C. O. Bartlett & Snow Co.

46A **Pressure Vessels**
Large and small pressure vessels for liquids or gas.
Posey Iron Works, Inc.

48A **Nickel-Base Alloys**
Description of corrosion resistance of propellers, shafts, thermometer wells and blow-off lines fabricated from Hastelloy.
The International Nickel Co., Inc.

(Continued on back of this insert)

Please do not use this card after August, 1954

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Advertisers' Products

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30A	32L	32R	33A	34A	216A	43A	44L	45A
46A	48A	49A	50L	51A	53A	54L	55A	56A
57A	58A	59A	60L	61A	62L	63R	65A	66A
67A	68L	69A	70L	71A	72L	73A	74A	83A
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97T	97B	98T	98B	99TL	99BL	99R	100TR	100BR
101T	101B	104T	104B	105BR	IBC	OBC		

Chemical Engineering Progress Data Service

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☐ I want a subscription. Bill me $6.00 for a year.

May, 1954

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46A	48A	49A	50L	51A	53A	54L	55A	56A
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67A	68L	69A	70L	71A	72L	73A	74A	83A
84T	84B	85A	86T	86B	87R	88B	89A	91R
92T	92B	93R	94L	94BR	95R	96L	96TR	96BR
97T	97B	98T	98B	99TL	99BL	99R	100TR	100BR
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May, 1954

PRODUCTS *(Continued)*

49A **Filtration Units**
Washing precoat unit, all stainless steel, cake shaving mechanism.
The Eimco Corp.

50L **Mist Eliminators**
Factory cut to fit vessel dimensions and contours. Can be made of practically any metal, to combat corrosion.
Metal Textile Corp.

51A **Cooling Towers**
Features open gravity distribution and "one glance" inspection.
The Marley Co.

53A **Flowmeters**
Constructed of stainless, used in many nuclear engineering projects.
Potter Aeronautical Co.

54L **Acid and Chemical Pumps**
Heavy duty pump. Capacities range 5 gal./min. to 7,500 gal./min.
Lawrence Pumps, Inc.

55A **Filters**
Features "H" horizontal filter that reduces down time to a minimum. Range of sizes up to 40,000 gal./hr.
Niagara Filters Div., American Machine and Metals, Inc.

56A **Pneumatic Transmitters**
For measuring differential, flow, pressure or level. Feature easy range change.
Republic Flow Meters Co.

57A **Conkey Equipment**
Filters, evaporators and crystallizers now fabricated in CB&I's plants.
Chicago Bridge & Iron Co.

58A **Stainless Steel Tubing**
Technical service for users of tubular products.
The Babcock & Wilcox Co., Tubular Products Div.

59A **Centrifugal Chempump**
Combined rotor and impeller assembly is the only moving part. ⅛ up to 3 hp.; capacity from 0 to 180 gal./min.
Chempump Corp.

60L **Plastic Pumps**
For difficult corrosive solutions and abrasive slurries.
Vanton Pump & Equipment Corp.

61A **Stainless Steel Castings**
Stainless steel fittings, valves and accessories.
The Cooper Alloy Foundry Co.

62L **Heavy Duty Mixers**
Dry, paste and special mixers. Capacity ranges from 1,000 to 2,000 lb.
Paul O. Abbé, Inc.

63R **Flowmeters**
Describes rupture-proof bellows and all-weather performance.
Barton Instrument Corp.

65A **Double Action Filters**
Air or gas, is mechanically cleaned, then rises at low velocity through radial finned filtering element or insert which removes the lighter air-borne material.
Dollinger Corp.

66A **Tubing and Pipe**
Features stainless tubing, and cooling coils.
The Carpenter Steel Co.

67A **Diatomaceous Silica Products**
For stepping up performance in paints, plastics, polishes, etc.
Johns-Manville

68L **Screw Conveyors**
Centrifugal casting machines turn out pipes ranging in 2½ in. to 31 in. O.D. and, according to diameter, up to 15 ft. long.
The Duraloy Co.

69A **Conveyor Type Dryers**
Increased drying capacity through system of air distribution. Small 8 ft. x 12 ft. units, to multiple-unit tunnel constructions several hundred feet long. Also batch and tunnel type truck dryers; cabinet type shelf or tray dryers; extruders and test dryers.
The National Drying Machinery Co.

70L **Permanite**
A thermosetting furfuryl alcohol resin, which can be fabricated into many types of corrosive handling equipment.
Maurice A. Knight

71A **Crystallization Equipment**
Shop view of unit 50 ft. high and 11 ft. 3 in. in base diameter. Crystal appearance also shown.
Struthers Wells Corp.

72L **Nuclear Engineering**
Research, development, engineering and design services.
Nuclear Development Associates, Inc.

73A **Compressors**
2,000-hp. synchronous motor compresses ammonia in two stages from 11 lb./sq.in. gauge to 215 lb./sq.in. gauge. Complete line for compression or evacuation of air or gas.
Ingersoll-Rand

74A **Development of Processes**
For the petroleum, natural gas, petrochemical and chemical industries.
The Fluor Corp., Ltd.

83A **Spray Dryers**
Bowen patented air cooling features used in the production of resins.
Bowen Engineering, Inc.

84T **Spray Nozzles**
Thousands of standard industrial spray nozzle types and sizes. Catalog.
Spraying Systems Co.

84B **Conveyor Belt Cleaners**
Removes materials from belts before they can be ground in. Adjustable.
Stephens-Adamson Mfg. Co.

85A **Cation Exchange Resin**
For water treatment. Also resins for the de-ashing and decolorizing of sugar syrups, and recovery of precious or toxic metals from wastes.
Rohm & Haas Co.

86T **Filtering and Filling**
Filters for small plant or batch lots of pharmaceuticals, cosmetics, chemicals, etc.
Ertel Engineering Corp.

PRODUCTS (*Continued*)

86B **Plug Valves**
Plug faces of corrosive-resistant rubber compound. Non-lubricated.
DeZurik Shower Co.

87R **Oxygen Analyzers**
Instruments that make a direct physical measurement on oxygen.
Arnold O. Beckman, Inc.

88B **Ejectors**
Steam jet air ejectors designed to meet conditions of individual installations.
Condenser Service & Engineering Co., Inc.

89A **Vacuum Furnaces**
10 to 1,000 pounds capacity. Movable retort resistance-heated furnaces for degassing and annealing in 10, 20 and 30-inch retort sizes, and others.
F. J. Stokes Machine Co.

91R **Heat Exchangers**
Evaporators, condensers, heaters and coolers. Bulletins.
The Whitlock Mfg. Co.

92T **Ribbon Blenders**
20 standard sizes, with capacities from 1 to 335 cu. ft. Also sifters, cutters, shredders, batch dumpers, etc.
R. N. Bailey & Co., Inc.

92B **Filtration Equipment**
Features "Filter Facts" booklet. Filter presses, filter media, and diaphragm pumps.
T. Shriver & Co., Inc.

93R **Valves**
Gate, globe and swing check valves to meet material specifications.
Pacific Valves, Inc.

94L **Silicone Defoamers**
Indicated to increase processing equipment capacity by eliminating space-wasting foam.
Dow Corning Corp.

94BR **Spray Nozzles**
For chemical spraying, cooling, humidifying, dehydrating, and other applications.
Binks Manufacturing Co.

95R **Vapor Recovery Systems**
Units for venting volatile or inflammable liquid storage.
The Vapor Recovery Systems Co.

96L **Mills**
Conical and tricone mills; rotary dryers, kilns, coolers; air classifiers; thickeners, clarifiers; constant-weight feeders; and cylindrical rod and ball mills.
Hardinge Co., Inc.

96TR **Stainless Steel Products**
Pipe, pails, pumps, rivets, scour cloths, sight flow glasses, taper pins, tubing, tubing fittings, ware, etc.
Schnitzer Alloy Products Co.

96BR **"Packaged" Plants**
Everything to assemble your plant is supplied with installation and operating instructions.
Foster D. Snell, Inc.

97T **Spectrograph**
New order sorter adds dimensions to quantitative and qualitative analyses.
Jarrell-Ash Co.

97B **Filtration**
Complete range of filter bases and a choice of six different closing devices. Catalog.
D. R. Sperry & Co.

98T **Crushers**
Designed for capacities beyond those of lab mills and below those required for large-scale operations. Equipped with rings or any of a full variety of hammers.
American Pulverizer Co.

98B **Plasticizer Oil**
Compatibility with GRS, neoprene, and buna N type rubbers.
Pan American Refining Corp.

99TL **Filters**
Porous stainless steel filters remove particles as small as 2/10 of a micron. Bulletin.
Micro Metallic Corp.

99BL **Steam Jet Ejectors**
Condensers and vacuum equipment. Corrosion resistant parts interchangeable with standard parts.
The Jet-Vac Corp.

99R **Catalysts**
To selectively hydrogenate acetylene in the presence of ethylene.
The Girdler Co.

100TR **Optical Pyrometer**
Self-contained, direct reading unit for high temperature measurements. Stock ranges from 1,400° F. to 7,500° F. or equivalent centigrade.
Pyrometer Instrument Co.

100BR **Turbo-Dryers**
For granules, beads, powders, crystals, pastes, sludges, and slurries.
Wyssmont Co.

101T **Special Processing Problems**
Resources for fabrication, including modern shop equipment for heavy sheet metal forming, specialty welding, and all machinery operations.
Artisan Metal Products, Inc.

101B **Meters**
To deliver predetermined quantities for batching. For continuous blending of two or more liquids.
Bowser, Inc.

104T **Micro-Microammeter**
Controls and records micro-currents to a hundredth of a millionth of a millionth of an ampere.
Beckman Instruments, Inc.

104B **Laboratory Planning**
"Labritecture" offers a basic method in laboratory planning, modernization, and expansion. Catalog.
Metalab Equipment Corp.

105B **Evactors**
Illustration shows two 4-stage evactors in pharmaceuticals plant. Also jet mixers, jet heaters, etc.
Croll-Reynolds Co., Inc.

IBC **Controlled Volume Pumps**
New controlled volume pump designed to eliminate leakage of corrosive or expensive liquids by being submersed in the liquid being pumped.
Milton Roy Co.

OBC **Fluid Mixers**
Turbine-type in sizes from 1 to 500 hp. and side entering sizes 1 to 25 hp. and portable sizes ⅛ to 3 hp.
Mixing Equipment Co., Inc.

EQUIPMENT

1 **Standardized Column-Sections.** Two models of Pfaudler Co. glassed-steel packed-type columns now available from stock. Large model sizes range 12 to 48 in I.D. in 10-ft. lengths., with clamped joints, porcelain support & distribution plates. Small model sizes made up of standard pipe & fittings, range from 2 to 8 in. I.D. All rated full vacuum to 25 lb./sq.in. gauge. Code construction.

2 **Distillation Apparatus.** Scientific Glass Apparatus Co., Inc., Dalin installation apparatus. Fractionation of charges from 2 ml. to 72 l. Standard columns supplied with boil-up rates as high as 30 l./hr. Operates as high as 350° C. Differential thermocouples supplement thermometers within each winding.

3 **Silicone Rubber.** Supertough silicone rubber with average tear strength of 190 lb./sq.in. developed by General Electric Co. Three grades. O rings & gaskets proved satisfactory as seals for synthetic base oils at 375° F. Flexibility over range —65° F. to 550° F.

4 **Conductivity Bridge.** General-purpose conductivity bridge for electrolytic & resistance measurements from Industrial Instruments, Inc. Sensitivity control to 1/3 of 1%. Range 0.2 ohms to 2,500,000 ohms with accuracy within 1%. Indicator is electron-ray eye tube.

5 **Kel-F Membrane.** New approach to difficult tank-lining jobs accomplished by use of Kel-F welded membrane from United States Stoneware Co. Corrosion resistant, for use in temperature range —100° F. to +350° F. Folder gives fabrication details, physical properties, chemical resistance table.

6 **Rotameter.** For safely measuring flow rate of liquids and gases Schutte and Koerting Co. announces the Safeguard rotameter. Steel meter case has detachable safety glass windows for protection of metering tube from shock; rigid construction eliminates pipe stresses on tube. Illustrated bulletin gives other data.

7 **Hygrol Machine.** Improved apparatus for treating air with an absorbent spray to fix humidity in air conditioning or drying. Model series 5700 combines air conditioner & absorbent reconcentrator. Size range from 1,000 to 5,300 cu.ft. of air/min. Niagara Blower Co.

8 **Pressure Transducer.** Added to North American Instruments, Inc. line is model GP-8 high-range pressure transducer. Ranges from 200 to 5,000 lb./sq.in. gauge & rated at 100% safe overload. Frequency from 2,000 cycles/sec. low to 10,000 cycles/sec. high. Weight 12 oz.

9 **Ultra-Viscoson.** Measures, records & controls viscosity. Bendix Aviation Corp. illustrated binder insert discusses speeding of production, labor saving, improved quality control, flexibility for laboratory work. Specifications & operation data, charts, etc., included.

10 **Multi-Channel Amplifier.** Wm. Miller Instruments, Inc. announces a multichannel d-c amplifier said to combine wide band width, high-grain, low-drift, high-input impedance. Unitized systems contain from 1 to 12 amplifier channels with matched power supply. Designed for exacting laboratory use.

11 **Alloy Steel Tubing.** Designed for use under high stress & temperature to 1200° F. is Universal Cyclops Uniloy 19-9DL alloy tubing from tubular products division of Babcock & Wilcox Co. Available in limited-size range in seamless & welded tube form. Corrosion resistant with oxidation resistance superior to austenitic stainless in same class.

12 **Solenoid Valve.** New piston-type action solenoid valve for automatic on & off control of air or water flow. Built of noncorrosive parts & packless construction. Sizes ⅜ to 1¼ in. pipe sizes. Hays Mfg. Co.

14 **Glassed Steel Reactors.** Of special interest to the process industries are new standard glassed-steel agitator-equipped reaction kettles from Pfaudler Co. Bulletin on various types & sizes. Standard stock permits usual delivery within ten days.

15 **Flowmeter.** Specification sheet from Potter Aeronautical Co. on new flowmeter said to measure fluids accurately under severe conditions. Remains accurate for hard-to-handle liquids at high temperatures & pressures. New principle of operation, easily installed. Accuracies to ±1/10 of 1% over long periods of operation.

16 **Beta-Gamma Survey Instruments.** Highly sensitive ionization beta-gamma survey instrument for detection of increments in radiation as small as .002 milliroentgens/hr. developed by Jordan Electronic Mfg. Co., Inc. Accuracy +10% of reading at all levels.

17 **Blinds & Spacer Rings.** Visi-Tab lightweight, lower cost blinds & spacer rings. Tab extends beyond pipe flanges providing easy identification of type of unit. Sizes for all standard pipe-line sizes, for raised face, ring-type joints, etc. Avaliable in various metals. Engineering Corp. of America.

18 **Proportioning Pump.** Improvement in design of model 1105-S proportioning pump by Proportioneers, Inc. Now offered as either 10- or 20-gal./hr. pump with open or explosion-proof motors & in various voltages. Available with standard or stainless steel trim, measuring cylinder assemblies & ceramic plungers.

19 **Radiation Detector.** Lightweight radiation detector new with North American Philips Co., Inc. Unit is about 1.7 in. thick, 4 in. wide, 6.6 in. high, weighs 25 oz. Designed for locating sources and measuring intensity of beta & gamma radiation. Operates from small batteries.

20 **Chlorinator.** Chlorinator A-701 from Wallace & Tiernan Corp. soon to be introduced. First of a series incorporating latest design developments. Features dual orifice meter operating automatically or manually. Capacity 1,000 lb./24 hr. Fiberglass pedestal, glass-enclosed mechanism.

21 **Flow Regulator.** W. A. Kates Co. announces production of a 275 gal./min. capacity self-operating liquid flow regulator as a new member of a complete line offering a wide range of sizes for most liquid-handling applications. New unit controls liquid flow rates at capacities from 50 to 275 gal./min. Equipped with 4-in. pipe connections. Other models 2 to 10 gal./min. All units for pressure variations of 125 lb./sq.in. gauge with accuracy of 3%.

22 **Flow Regulator.** Catalog binder insert covering self-operated flow regulator for clean, gas-free liquids. Constant flow rate maintained by use of energy from flow stream without external power supply. Unaffected by position. May be equipped with diaphragm motor motor valve for remote setting. Operation described, cross-sectional views. Fischer & Porter Co.

23 **Recording Oscillograph.** Said to provide added data capacity of 44% new 26-trace recording oscillograph from Consolidated Engineering Corp. Records from static conditions to 3,000 cycles/sec.

24 **Pressure Monitor.** Calibrated readings of any dynamic pressure said to be available from Control Engineering Corp. new pressure monitor. Can be used with any 2- or 4-arm strain gauge transducer & standard oscilloscope. Contains plugin two-stage amplifier. Unique calibration circuit.

25 **Centrifugal Pump.** Adaptable particularly to stainless steel & monel construction newly designed centrifugal pump. Said to be revolutionary in providing at least 25% better efficiency at lower cost than currently available units of like construction. Equipped with top quality mechanical seals, ball bearing 3,400 rev./min. electric motors in ½, ¾, 1 & 1½ hp. sizes. Heinicke Instruments.

26 **High Pressure Controlled Volume Pump.** HyROYmetric new controlled volume pump announced by Milton Roy Co. for pressures to 50,000 lb./sq.in. & capacities to 1,350 gal./hr. Wide range of materials of construction, powered by air or electric motor. Capacity regulated manually or automatically through driver speed variation. Adjustable stroke length from 0 to 100% during operation.

27 **Liquid Sample Counter.** A liquid sample attachment said to be highly sensitive in measuring of gamma emitting liquids presented by Nuclear Research & Development, Inc. Unit designed for counting low level activity in small volume liquid samples to 5 cc.

28 **Synthetic Rubber.** Kel-F fluorocarbon elastomer, a revolutionary synthetic rubber, said to have properties not available in other rubber products has been developed by M. W. Kellogg Co. Uniquely resistant to corrosive chemicals, acids, hydrocarbon fuels & lubricants, oxygen, ozone, sunlight. Nonflammable, tough, heat & abrasion resistant. May be processed & vulcanized on conventional rubber equipment. Serviceable in temperature range —15° F. to 400° F. Applications include fuel hose, gaskets, seals, tank linings.

29 **Rotary Union.** Well-illustrated bulletin from Perfecting Service Co. announces a newly designed rotary union featuring low friction ball bearing & mechanical seal construction to reduce wear & power consumption. Applies to standard ½ to 2 in. pipe sizes for use on steam, water, air, gas or oil applications to 250 lb./sq.in. Other information, cutaway views, etc.

30 **D. C. Amplifier.** Said to be a new approach to industrial & laboratory d-c amplifiers, announced by Fielden Instrument Division of Robertshaw-Fulton Controls Co. Convert low level d-c microamperes or millivolt inputs to high level d-c current output. For use in measuring or recording of low level d-c signals & in industry as thermocouple amplifier.

CHEMICALS

54 **Hand Cream.** Kerodex, medically tested hand cream for protection against many industrial skin hazards. Developed in Great Britain during World War II. Protection against contact dermatitis due to acids, alkalis, solvents, etc. & other primary irritants, also against sensitizing agents such as nickel, rubber, chromates, etc. Three types available: wet work, dry work, & exposure to radiation.

55 **Plastic Lead Seal.** A plastic lead seal pipe thread & gasket-sealing compound available in handy 1-lb. brush-top cans. Underwriter approved, permanent, nonhardening. For pressures to 6,000 lb./sq.in., temperatures to 500° F., insoluble in water, steam, gas, refrigerants & petroleum products. Bulletin. Crane Packing Co.

56 **Graphite.** Graph-I-Tite carbon-impregnated graphite is more than 99.5% pure graphite. Operates at temperatures as high as 5700° F. Not wetted by molten metals or salts. Extends limits of chemical & metallurgical equipment design. Bulletin covers properties, applications, availability in several grades. Falls Industries, Inc.

57 **Silicone Glass Laminates.** Dow Corning Corp. reports Dow Corning 2106 silicone, low-pressure laminating resin providing high physical strength and fast cure at room & elevated temperatures. Flexural strength of 10,000 lb./sq.in. at 500° F. reached in 6 hr. Laminates exhibit water repellence & resistance to common inorganic reagents.

58 (58) Scintillation crystals for use in detection & measure-
59 ments of ionizing radiations. Efficient & with good resolving power. Bulletin describes types in most common use. (59) Plastic Phosphor for use in scintillation counting. Solid solution of highly purified phosphor activators in clear thermoplastic resin, similar to polyvinyl toluene physically, & easily machined. Bulletin available. National Radiac, Inc.

60 **Solvents Wall Chart.** Solvents produced by American Mineral Spirits Co., listed in convenient wall chart.

61 **Methyl Amyl Acetate.** Technical bulletin gives physical & physiological properties, specifications, solubilities, performance data. Substance is high-boiling, slow-evaporating solvent for lacquers, pharmaceutical manufacture, etc. Carbide and Carbon Chemicals Co.

62 **Fatty Acids.** A collection of 35 data sheets on fatty acids produced by chemical division of General Mills, Inc. Descriptions, uses, specifications, compositions, etc.

63 **Sealing Compound.** A chemically inert pipe thread sealing compound with pure Teflon base called Teffilm by Eco Engineering Co. Two consistencies offered both suitable for use with all chemicals to which Teflon is inert & for temperatures to 400° F.

64 **Fullers Earth Products.** Attapulgus Minerals & Chemicals Corp. booklet on process uses of Attapulgite naturally-active, adsorptive fullers earth. Flow sheets, tables of properties, data.

65 **Amines.** Binder insert data sheets from General Mills, Inc. on its lines of tallow amines & amine acetates. Descriptions, uses, specifications.

66 **Silicone Fluids.** Data sheets on Viscasil silicone fluids available from General Electric Co. Include descriptions, physical properties, lubricity, toxicity, solubility, and applications data.

67 **Amylamines.** Now available in semicommercial quantities are amylamine, diamylamine, triamylamine from Sharples

Chemicals, Inc. Applicable as oil-soluble catalysts, corrosion inhibitors, acceptors, extractants & intermediates for production of oil-soluble rubber & agricultural chemicals, pharmaceuticals, surface-active agents, dyes.

68 **Fatty Alcohols.** Revised data sheet on 15 types of Cachalot brand alcohols listing physical properties and availability data. M. Michel and Co., Inc.

69 **Soap & Synthetic Detergent Buying Guide.** A 1954 edition of Colgate-Palmolive Co. soap & synthetic detergent buying guide now available. Gives résumé of line of industrial products in concise, easy-to-read form. Several new products.

BULLETINS

70 **Freeze Drying.** Describing the processes used. Brochure from F. J. Stokes Machine Co. Equipment described for use in foods & pharmaceuticals.

71 **Analytical Service.** Specialized problems in chemical analysis, process monitoring, isotope-ratio determination solvable only by use of spectrometer-type instruments are included in service offered by Consolidated Engineering Corp. Bulletin on all phases of service.

72 **Metalizing.** Folder on the benefits of the metalizing process contains photos, drawings & descriptive copy on applications in industry. Use for various metals applied, information on shop & field facilities contained in folder from Coatings div., Metalweld, Inc.

73 **Low-Temperature Processing.** Booklet on techniques, specialized equipment, present process applications with flow sheets, facilities available from Air Products, Inc. Sections on oxygen-nitrogen-argon generators, cylinder gases, etc.

74 **Power Transmission Equipment.** Flexible couplings, V-belts, counter-shafts, sheaves, by Lovejoy Flexible Coupling Co. Illustrated catalog of ratings, dimensions, applications, other data.

75 **Electrunite Tubes.** Carbon steel condenser & heat-exchanger tubes described in illustrated catalog from Republic Steel Corp.

76 **Shaft Seal.** Type 9 shaft seal for high temperatures & corrosive services. Has stationary seat, lapped sealing faces, machined carbon washer, other features. Data sheet on operation, construction, materials, applications. John Crane.

77 **Process Equipment.** J. P. Devine Mfg. Co. illustrated catalog on mixers, mills, blenders, vessels, vacuum pumps. Descriptions.

78 **Lubricators.** High-pressure lubricators designed for connection to gear motors from Manzel, division of Frontier Industries, Inc. The models rated 20,000 & 30,000 lb./sq.in. gauge. Reservoir arranged for steam or self-contained electric heater & thermostat. Folder shows schematic diagrams.

79 **Cycloflow Valves.** A four-position single-control valve for regulation of flow through ion-exchange equipment. Conoflow Corp. booklet describes function, operation, design, construction, other features. Available in sizes 1½ to 4 in.

80 **Electronic Instruments.** Catalog J-1 from Boonton Radio Corp. on generators, inductors, accessories. Lists specifications, information on coil & condenser testing, oscillator ranges, dimensions.

81 **Spray Equipment.** "Spray Tips," leaflet from Eclipse Air Brush Co. discusses fundamentals of paint spray equipment.

82 **Nuclear Storage Containers.** General Lead Construction Corp., lead-shielded containers & lead bricks for radioactive materials. Folder.

83 **Waste-Disposal Engineering.** Gilbert Associates, Inc. catalog describing processes for disposal and recovery of industrial wastes, also Gilbert engineering facilities.

84 **Stainless Steels.** Illustrated catalog of plates, heads, circles, sheets, forgings & billets, bars from Carlson Engineering Service.

85 **Heat Exchangers.** Easily accessible plate-type heat exchangers from Delaval Separator Co. illustrated & described in folder. High heat transmission coefficient, other features listed with cross-sectional views, construction details.

86 **Nickel Alloys Products.** Stainless Welded Products, Inc. binder insert design manual contains chemical & physical properties, corrosion-resistance data, tank capacities, beam formulae, etc. A.S.M.E. code calculations.

87 **Steam Traps.** Thermodynamic compact steam traps from Sarco Co., Inc. Bulletin describes operation, gives schematic drawings, specifications.

88 **GATX Products & Services.** Bound catalog from General American Transportation Corp. describes its tank and bulk solids car-leasing services, car building, tank-storage terminals, process-equipment fabrication services, gasholders, dryers, Turbo-mixers, Kanigen nickel-plating process, & other products & services. Illustrated.

89 **Multi-Wash Collectors.** Illustrated bulletin describes wet-type dust collectors, their method of operation, various models with details on each, special features, other data. Claude B. Schneible Co.

90 **Electric-Heating Applications.** Booklet from Edwin L. Wiegand Co., illustrates & describes approved methods of electrically heating liquids, air, gases, machine parts, process equipment. Illustrated case histories. Section on infrared radiant heating.

91 **Gauges, Valves, Specialties.** Jerguson Gage & Valve Co. liquid level gauges & gauge valves for wide variety of types of liquid, with variety of connections, gaskets. Illustrated folder. Specifications.

92 **Barometric Condensers.** Floor-mounted direct-contact barometric condensers for use where headroom is limited. Folder contains cut-away views of units, showing vapor & condensing water flow. Barometric leg (32 to 34 ft.) eliminated. Ingersoll-Rand Co.

93 **Flow & Pressure Control Instruments.** Catalog of Fischer & Porter Co. Flowrator variable-area flowmeters, recorders, controllers, pressure regulators. Specifications, sizing nomogaphs, etc. included.

94 **Dowtherm Vaporizers & Heaters.** Eclipse Fuel Engineering Co. Dowtherm vaporizers & heaters for high temperature, low-pressure vapor- & liquid-phase process heating. Completely automatic. Illustrated binder insert catalog lists features, applications, tables of data.

95 **Vapor Condenser.** Standard stainless steel vapor condenser for chemical & process industries from Doyle & Roth Mfg. Co., Inc. ASME standards govern fabricating procedures. Standard components stocked.

SPRAY DRYER PIONEER

Plaskon (lately acquired by Barrett Division of Allied Chemical & Dye Corporation) first made resin available in dry powder form by use of Bowen Spray Dryer

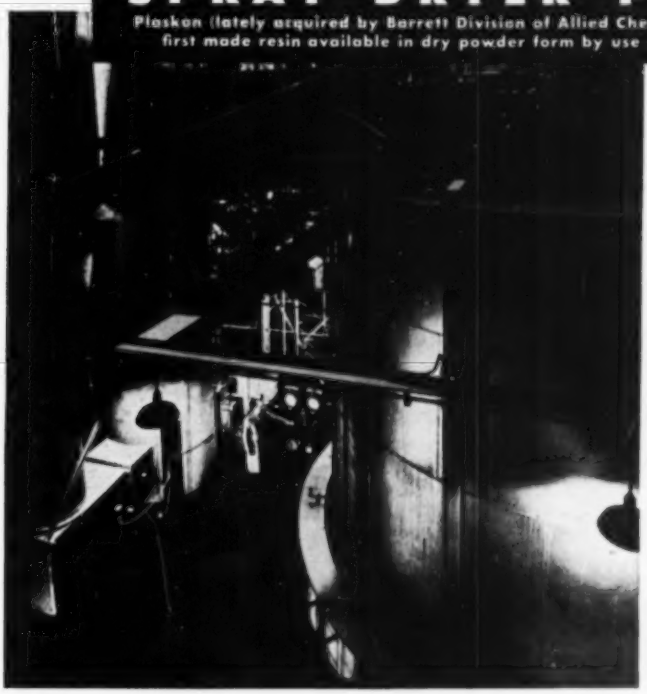


Illustration shows one of the three Spray Dryers embodying Bowen patented air cooling features used by Barrett in the production of Plaskon® resins.

Plaskon is now a registered trade mark of Allied Chemical & Dye Corporation.

Plaskon First in Powdered Resin Field

Phenol formaldehyde and urea formaldehyde resins were originally marketed solely in liquid form. Plaskon, recently acquired by Barrett Division of Allied Chemical & Dye Corporation, produced the first powdered resins just prior to the war. The demand for this powdered product during the war was so great that the original Bowen Spray Dryer purchased by Plaskon was supplimented by two additional units.

The thermo plastic and thermo-setting characteristics of resin powder makes this material very difficult to produce. The large production during the war by Plaskon and other resin manufacturers was made possible only by the use of spray drying equipment embodying Bowen patented air cooling features.

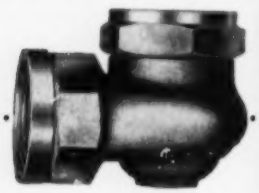
Bowen Engineering is proud to have had the opportunity to cooperate in this project.

BOWEN ENGINEERING, INC.
NORTH BRANCH 13, NEW JERSEY

BOWEN SPRAY DRYERS
Always Offer You More!

Recognized Leader in Spray Dryer Engineering Since 1926

SPRAYING SYSTEMS CO.



for lower cost

and better performance

SPRAY NOZZLES

Modern design. Precision machining. All materials. Thousands of standard industrial spray nozzle types and sizes to choose from. Years of proved experience at your service.

write for this great new catalog today

Ask for our new 48 page Catalog No. 24 . . . the most comprehensive spray nozzle catalog ever produced. Yours for the asking.

SPRAYING SYSTEMS CO.
3284 Randolph Street • Bellwood, Illinois

Clean CONVEYOR BELTS Last far Longer!

INSTALL S-A SPRING-TYPE CONVEYOR BELT CLEANER

Multiple Blades Keep Belt Clean and Dry

• Removes wet or dry material from belts before they can be ground into belt by return pulleys and idlers. Adjustable to fit any conveyor. No moving parts, no power required. Easily installed by your own plant personnel. *Cost little, saves a lot!*

MAIL COUPON FOR FULL DETAILS →

STEPHENS-ADAMSON MFG. CO. (S-A)
Standard Products Division
57 Ridgeway Ave., Aurora, Ill.
Please send me Bulletin 651 on Conveyor Belt Cleaners.
Name_____
Company_____
Address_____
City_____ Zone____ State____

CANDIDATES FOR MEMBERSHIP IN A. I. Ch. E.

The following is a list of candidates for the designated grades of membership in A.I.Ch.E. recommended for election by the Committee on Admissions.

These names are listed in accordance with Article III, Section 7, of the Constitution of A.I.Ch.E.

Objections to the election of any of these candidates from Active members will receive careful consideration if received before June 15, 1954, at the Office of the Secretary, A.I.Ch.E., 120 East 41st Street, New York 17, N. Y.

Applicants for Active Membership

Arkis, Jerome W., *Godfrey, Ill.*
Banks, Willis L., *Arlington, Va.*
Barduhn, Allen J., *Austin, Tex.*
Bernstein, George J., *Lemont, Ill.*
Bigos, Joseph, *Pittsburgh, Pa.*
Bogen, Alfred T., Jr., *Palembang, Sumatra, Indonesia*
Bradberry, A. O., *Los Angeles, Calif.*
Burton, W. Page, *Little Silver, N. J.*
Cushing, David G., *Kennett Square, Pa.*
Damskey, L. R., *Rodeo, Calif.*
Drexel, R. E., *Wilmington, Del.*
Edgar, Robert T., *Baton Rouge, La.*
Edmondson, Keith H., *Kalamazoo, Mich.*
Eggert, Jay P., *Eggertsville, N. Y.*
Fish, William Morgan, *E. St. Louis, Ill.*
Grossman, Adrian Jacques, *Albany, N. Y.*
Haas, D. Marshall, *Baytown, Tex.*
Hanson, Leonard W., *South Charleston, W. Va.*
Hough, J. G., *Baltimore, Md.*
Huse, Herbert W., *Swarthmore, Pa.*
Ireland, John D., *Columbus, Ohio*
Jones, E. Madison, *Texas City, Tex.*
Jones, Hershul T., *Port Arthur, Tex.*
Klima, Beverly Bartley, *Oak Ridge, Tenn.*
Kniskern, C. L., *North Chicago, Ill.*
Lukat, Robert T., *Sterlington, La.*
Lundeen, Robert W., *Concord, Calif.*
Magovern, Robert L., *Emeryville, Calif.*
Mellow, Ernest W., *Evans City, Pa.*
Moser, Charles E., *New York, N. Y.*
Naschke, John H., *Houston, Tex.*
Packer, G. V., *Richland, Wash.*
Panula, Gustaf H., *Midlothian, Ill.*
Perkins, Myrle M., *Plandome, L. I., N. Y.*
Phinney, John A., *Pittsburgh, Pa.*
Pressburg, Bernard Samuel, *University, La.*
Richardson, James A., *Dallas, Tex.*
Ross, James D., Jr., *Coatesville, Pa.*
Rue, William J., *Radford, Va.*
Smith, Ernest L., *Shreveport, La.*
Smith, Julian C., *Ithaca, N. Y.*
Smith, Wm. C., *Houston, Tex.*
Snyder, Nathan William, *Berkeley, Calif.*
Stephens, Lloyd H., *Baton Rouge, La.*
Strum, Albert, *Flushing, N. Y.*
Vines, George W., *Pittsburgh, Pa.*
York, J. Louis, *Ann Arbor, Mich.*

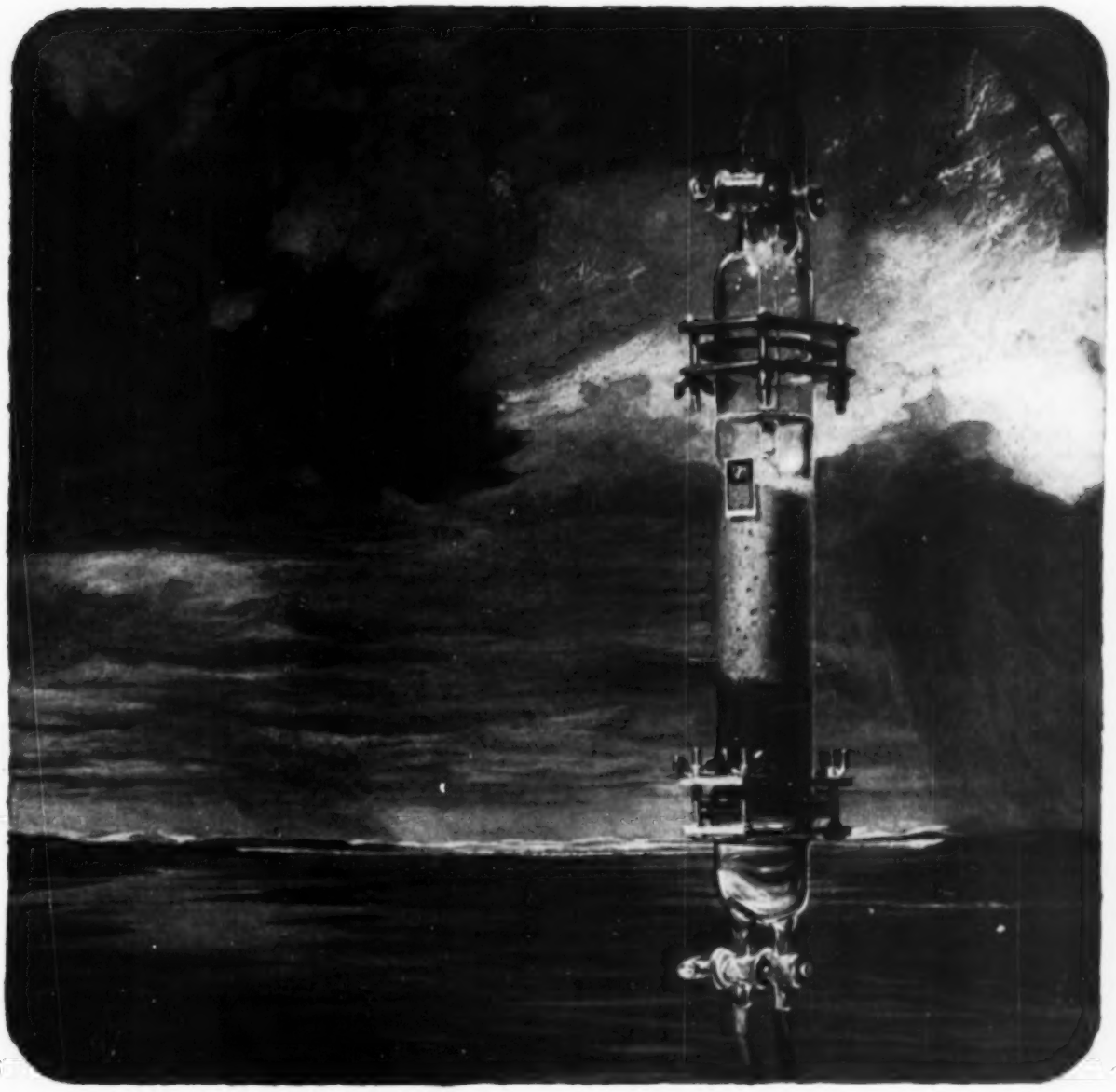
Applicants for Associate Membership

Avels, Robert E., *Indianapolis, Ind.*
Butler, Roger M., *Kingston, Ontario, Canada*
Ganske, Warren L., *Minneapolis, Minn.*
Mohler, Donald, *Schenectady, N. Y.*
Neumann, Albert L., Jr., *Wilmington, Del.*
Perrine, J. Harold, *Marcus Hook, Pa.*
Tuve, Richard L., *Washington, D. C.*
Walters, William Monroe, *Eleanor, W. Va.*

Applicants for Junior Membership

Aelion, Marc L., *Sao Paulo, Brazil*
Andros, Arthur A., *Hingham, Mass.*
Aspy, William L., Jr., *Kingsport, Tenn.*
Bates, Paul B., *Waynesboro, Va.*
Bell, Thomas R., *Pasadena, Calif.*
Berenguer, F., *Colombia, S. A.*
Burke, Robert L., *Easton, Pa.*
Burks, William M., Jr., *St. Louis, Mo.*
Calkins, Kenneth W., *Pampa, Tex.*
Carl, Paul R., *Woodbury, N. J.*
Chantry, W. A., *Pleasant Hill, Calif.*
Cherry, Robert Homer, Jr., *Baton Rouge, La.*

(Continued on page 86)



8,000,000 gallons from 1 cubic foot

One cubic foot of long-lasting AMBERLITE® IR-120 cation exchange resin has treated 8,000,000 gallons of water—enough for a family of four for 77 years—in one of the nation's largest municipal water-softening plants.

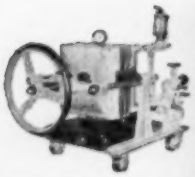
This resin is typical of those produced by Rohm & Haas Company, where the search for new ion exchange resins and techniques is as unceasing as man's quest for good water. In laboratory columns like the one above, industrial processes were developed for the preparation of high quality boiler-feed water, for the de-ashing and decolorizing of sugar syrups, for the recovery of precious or toxic metals from wastes.

If your process involves water treatment or the removal or replacement of ions in solution, details on the AMBERLITE ion exchange resins may help you.

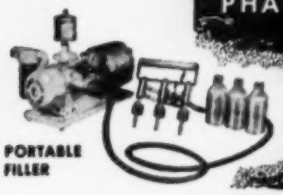
Ask for "If You Use Water . . .", a 28-page booklet of basic information on the ion exchange treatment of water.

ROHM & HAAS COMPANY

THE RESINOUS PRODUCTS DIVISION, PHILADELPHIA 5, PENNSYLVANIA



EFS-B FILTER



PORTABLE FILLER

For FILTERING and FILLING

small plant or batch lots of

PHARMACEUTICALS, COSMETICS, CHEMICALS, FOODS, DRUGS, SOAPS, ETC.

Two Ertel units that make small production efficient. They have all the desirable features of Ertel high production equipment: EFS-B FILTER has single hand wheel for simple trouble-free operation, bronze or stainless circulatory system, accommodates accepted Ertel Asbestos Filter Sheets. PORTABLE FILLER has automatic overflow system, non-drip spouts, bottle size flexibility up to gallons. And, both units can be easily moved from place to place. Write for detailed information on this important equipment . . . it belongs in your plant.

ERTEL ENGINEERING
CORPORATION
KINGSTON 4, NEW YORK
Branch Office & Showroom Located in New York City
COMPLETE LINE OF
Liquid Handling Equipment

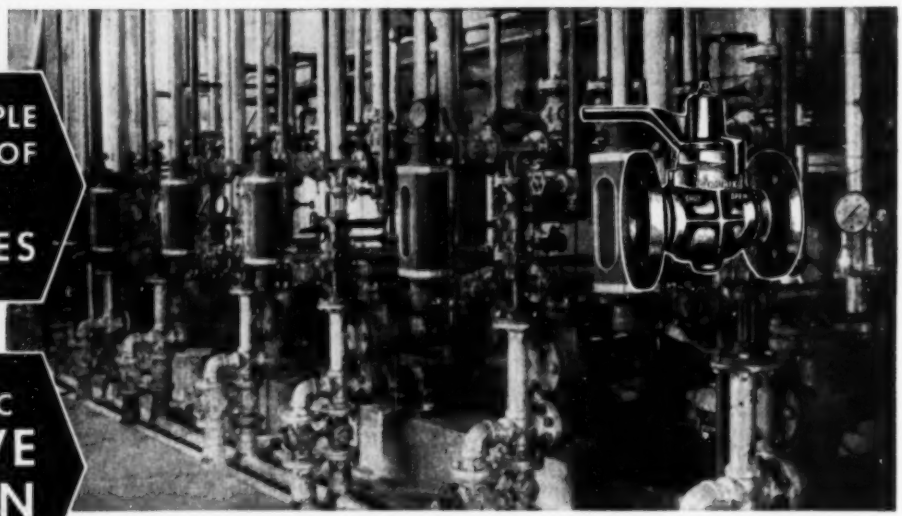
ERTEL

CANDIDATES *(Continued from page 84)*

Corder, Jesse Lee, *St. Louis, Mo.*
Cotten, Hilton Ivy, Jr., *Port Sulphur, La.*
Craddock, William F., *Nashville, Tenn.*
Day, Bryan, *Baton Rouge, La.*
DeBorde, Donald D., *Texas City, Tex.*
Derr, John McKee, *Ashtabula, Ohio*
Doyle, Arnold W., *Dorchester, Mass.*
Duvall, Bryan V., *Clarksville, Ind.*
Elmblad, Thomas R., *Harvey, Ill.*
Fagan, Walter S., *Chicago, Ill.*
Fahien, Raymond W., *Baton Rouge, La.*
Feldkirchner, Harlan, *Maywood, Ill.*
Freund, Frederick J., *New York, N. Y.*
Frimodig, Mark M., *St. Louis, Mich.*
Hagstrom, Paul E., *Charleston, W. Va.*
Hahn, Thomas J., *Dearborn, Mich.*
Herrmann, John W., *Woodside, N. Y.*
Holm, Bart E., *Keystone, Fla.*
Holmes, John M., *New Castle, Del.*
Huber, Robert C., *Elkhart, Ind.*
Jang, Roland, *Berkeley, Calif*
Kahn, Samuel C., *Belle, W. Va.*
Kelleher, James P., *Newark, N. J.*
Kellett, John W., *Roselle, N. J.*
Kogos, Lawrence, *Edgewood, Md.*
Kouzel, Bernard, *Allentown, Pa.*
Lau, E. F., *Royal Oak, Mich.*
Matusevich, Steve, Jr., *Orange, Tex.*
McClure, R. L., *Wilmington, Del.*
McKain, Thomas J., *Houston, Tex.*
Metzler, Charles V., *Louisville, Ky.*
Nadel, Marvin, *Philadelphia, Pa.*
Neunuebel, Robert F., *Brentwood, Mo.*
Noble, Matt A., Jr., *Baton Rouge, La.*
Potter, Carl H., Jr., *Binghamton, N. Y.*
Quigley, Harry A., *Summit, N. J.*
Ramalho, Rubens S., *Nashville, Tenn.*
Reuther, Richard H., *Portsmouth, N. H.*
Rhoads, David H., Jr., *Philadelphia, Pa.*
Ricks, Francis Harold, *Indianapolis, Ind.*
Shelton, Louis G., *Lake Jackson, Tex.*

ANOTHER MULTIPLE INSTALLATION OF DeZURIK PLUG VALVES

FOR A SPECIFIC CORROSIVE SITUATION



ALUMINUM-BODY DeZURIK PLUG VALVES, with plug faces of special corrosive-resistant rubber compound, are key factors in this intricate processing system. They provide the ideal, trouble-free answer to a specific corrosive condition.

In the same system, on related non-corrosive lines, iron-bodied DeZurik Valves with rubber-faced plugs are employed. Here's one more case where there's a non-lubricated DeZurik Plug Valve that fits each specific job, with the easiest, most carefree operation attainable!

Write for Bulletin or for recommendations to fit your valving problem:

DeZURIK SHOWER CO.
SARTELL, MINN.

Shultz, Eugene B., Jr., Chicago, Ill.
Simons, Arthur G., Jr., Texas City, Tex.
Smith, John C., Baltimore, Md.
Steffanson, Robert S., Midland, Mich.
Tabler, Donald C., Bartlesville, Okla.
Taylor, Raymond E., Burlington, Iowa
Thorson, Donald R., Rifle, Colo.
Treat, Leo H., Dearborn, Mich.
Troscinski, Edwin S., Argo, Ill.
Tyman, Paul M., Denver, Colo.
Valle-Riestra, J. Frank, Pittsburg, Calif.
Walters, Robert B., Terre Haute, Ind.
Wiederhorn, Robert, Pittsburgh, Pa.
Wing, Harold F., San Jose, Calif.
Yamartino, Raymond L., Waltham, Mass.
Zimmer, Harry J., Berkeley, Calif.

NEWS

(*Continued from page 70*)

SHELL INCREASES FELLOWSHIPS BY 50%

A nearly 50% increase in expenditures for fundamental research and fellowship programs in American universities during 1954-55 has been announced by the Shell Fellowship Committee for Shell Chemical Corp., Shell Development Co., Shell Oil Co., and Shell Pipe Line Corp. The amount spent will be increased from $177,500 to $263,000.

The grants are in chemical engineering and other sciences. Each fellow receives $1,500 for his personal use, and his tuition and fees are paid. In addition, the school is reimbursed for the fellow's research expenses. Students in the final year of doctorate study are preferred, but awards may be made to other graduate students selected by the universities. The fundamental research grants of $5,000 are made to specific departments to aid them in developing their research facilities. A supplemental grant of $2,500 is made to the school for unrestricted use.

CANADIAN INSTITUTE NAMES NEW HEAD

Donald McGregor Stephens of Winnipeg, Man., will be the next president of The Engineering Institute of Canada, it was announced last month. Mr. Stephens is chairman and general manager of The Manitoba Hydro-Electric Board and president and general manager of the Winnipeg Electric Co. While deputy minister of the Manitoba Department of Mines and Natural Resources, from 1938 to 1951, he served on two international engineering committees dealing with boundary-water matters.

Have you this LATEST DATA

on the revolutionary

Arnold O. Beckman INC.

OXYGEN ANALYZERS?

Throughout industry — wherever oxygen content of gases influences or controls chemical processing or combustion operations — Arnold O. Beckman Oxygen Analyzers are establishing completely new standards of accuracy, simplicity and convenience. These are the *only* instruments that make a direct physical measurement on oxygen itself — not of some variable secondary relationship.

Have *you* fully investigated the vital savings to be made by this revolutionary measuring principle in *your* operations? Are you aware of the latest money-saving applications for this equipment? If not, send for the following helpful literature. It's free!

BULLETIN 103: *Describes the Model G-2 Beckman Oxygen Analyzer — the instrument to use where maximum accuracy is essential. Model G-2 ranges are available for oxygen concentrations as low as 0-1000 parts per million — as high as 95-100% — or virtually any other range or combination of ranges. Bulletin 103 describes the unique magnetic operating principle used in Model G-2 Analyzers, equipment, accessories and typical applications.*

BULLETIN 108: *Describes the Model F-3 Beckman Oxygen Analyzer — the instrument designed primarily for industrial applications such as combustion control, catalyst regeneration, sulfur grinding, etc., which require an oxygen measuring range of 0-5%, 0-10%, 0-15% or higher. Bulletin 108 describes the unique magnetic operating principle used in Model F-3 Analyzers, gives equipment specifications and typical applications for this instrument.*

BULLETIN AD607: *Contains helpful charts and data on most efficient methods of controlling various combustion processes.*

BULLETIN AD610: *Contains helpful data on Chemical Applications, illustrates a typical installation, lists equipment required.*

BULLETIN AD611: *Contains helpful data on Tunnel Kiln Applications, shows typical installation, details equipment required.*

BULLETIN AD613: *Contains helpful data on measuring O_2 content of High Purity Gases, shows typical sampling system, lists equipment required.*

The above informative literature will gladly be sent you free. For maximum convenience, use the coupon at right.

Arnold O. Beckman INC.

1020 Mission Street, South Pasadena 3, California

Please send Bulletins checked below:

☐ 103 ☐ 108 ☐ 607 ☐ 610 ☐ 611 ☐ 613

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Company and Address _____

_____

_____

Position _____

AMENDMENTS TO ATOMIC ENERGY ACT OFFERED

Proposed amendments to the Atomic Energy Act of 1946 have been presented to the Senate and the House of Representatives by Senator Bourke B. Hickenlooper and Representative W. Sterling Cole, vice-chairman and chairman respectively of the Joint Committee on Atomic Energy. The bills, S. 3323 and H.R. 8862, cover in particular international cooperation, licensing, patents, dissemination of information, and definition of materials concerned.

Main provisions of the bills are briefly as follow: (1) The president would be empowered to enter into agreements with allies on uses of atomic energy, such agreements being subject to the approval of the Joint Committee. (2) Nonexclusive licenses for nonmilitary utilization of nuclear materials would be granted for periods up to 10 years to United States businesses, all subject to stringent regulation by the A.E.C. (3) No patents would be hereafter granted for any invention or discovery useful solely in employing plutonium or enriched uranium in atomic weapons. (4) Restricted data would automatically become unrestricted at the end of 3 years except under special circumstances, and dissemination of technical information would be speeded. (5) Any material capable of releasing energy through nuclear fission or through nuclear transformation would come under the provisions of the Act.

The bills have been referred to the Joint Committee on Atomic Energy.

E.J.C. SURVEYS ENGINEERS' EARNINGS

Publication of "Professional Income of Engineers—1953," the report of a survey conducted in 1953 by the Special Surveys Committee of the Engineers Joint Council, was announced last month. In tabular and graphic form the report presents the earnings of engineers in twenty-six types of industry. Earnings of those in engineering education included income from consultative work as well as academic income.

The samples obtained represent, according to the committee, 295 companies with a total employment of more than 2½ million and an engineering employment of 65,169. Twelve government agencies employing 3,892 engineers also submitted data. There is no information on self-employed engineers. In all, the samples "represent about 18% of the engineers employed in industry, 30% of those engaged in engineering education, and 4% of those employed in government, not including the armed services." There was no attempt to classify the returns according to engineering specialization.

The report covers 32 pages in all and may be obtained at $2 a copy or, for members of constituent societies of E.J.C., at $1 from the Engineers Joint Council, 29 West 39 St., New York 18.

SCALE MODEL ATOMIC PILOT PLANT DISPLAY

A scale model of an atomic pilot plant will be displayed by North American Aviation Co. at the First International Instrument Congress and Exposition in Philadelphia from Sept. 15 to 21, 1954. North American has announced design of an atomic power generator and is prepared to build a pilot plant for $10 million to demonstrate and study the production of electrical power for industrial uses. The proposed plant will generate about 8,000 kw. of electrical power, enough to supply 2,000 average homes with electricity. Although the cost of producing electricity by this method would be considerably higher than by coal or water power at present, the company hopes that more nearly competitive methods of power production from atomic energy can be developed.

(*More News on page* 91)

CONSECO **SteamJet Air EJECTORS**

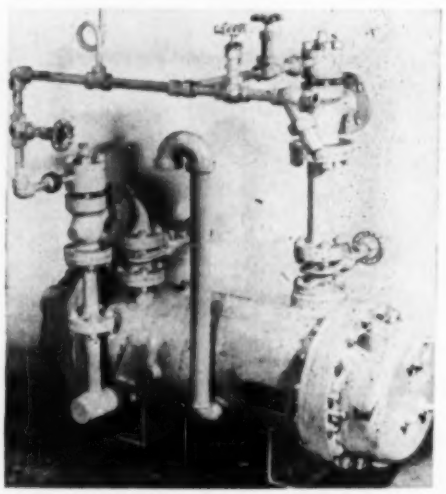
Save Operating Dollars

"Conseco" Ejectors assure economical trouble-free performance, combined with low steam consumption and stable operation over the entire vacuum range, because they are DESIGNED TO MEET CONDITIONS OF INDIVIDUAL INSTALLATIONS.

The "Conseco" line includes single and multiple designs for process and power plants. Years of laboratory development plus a great volume of operating data combine to assure the satisfactory operation of every "Conseco" installation.

WRITE FOR BULLETIN

▲ Single element single stage non-condensing ejector for evacuating, priming, or maintaining vacuum to 26.5" hg. built in standard or corrosion resisting materials.



Single element two stage condensing ejector. Built in any materials with surface or barometric condensers. For maintaining continuous vacua up to 29.5".

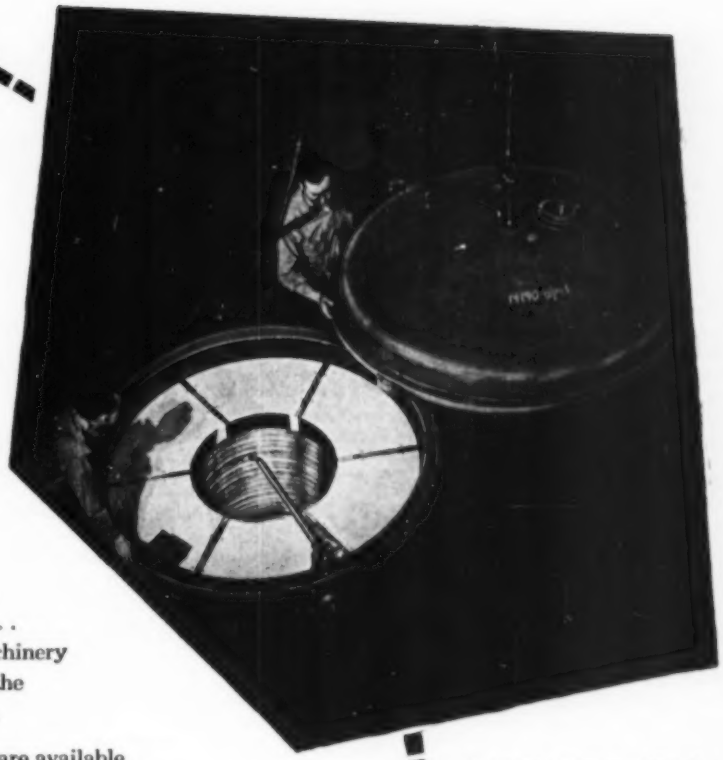
"CONSECO" PRODUCTS AND SERVICES

Retubing	Tube Plugs	Blackburn-Smith
Condensers	Conco Plug and Guns	Filters and
Evaporators	Bevel Gears	Grease Extractors
Air Ejectors	Instrument Repair	Metal Spray
Heat Exchangers	Service	
Flowrites	*Bulletin Available for Above Items*	

CONSECO **Condenser Service & Engineering Co., Inc.**

64 BLOOMFIELD STREET, HOBOKEN, N. J. • Hoboken 3-4425 • N. Y. Tel.: BArclay 7-0600

It's Experience that Counts in Building Vacuum Furnaces



A Stokes induction-heated vacuum melting furnace.

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Assistant Chairman

L. J. Coulthurst, Foster Wheeler Corp. 165 Broadway, New York 6, N. Y.

MEETINGS

Ann Arbor, Mich., Univ. of Mich., Ann Arbor, Mich., June 20-25, 1954—Conference on Nuclear Engineering.

TECHNICAL PROGRAM CHAIRMAN: D. L. Katz, Chairman, Dept. of Chem. and Met. Eng., Univ. of Mich., 2028 E. Eng. Bldg., Ann Arbor, Mich.

Glenwood Springs, Colo., Hotel Colorado, Sept. 12-15, 1954.

TECHNICAL PROGRAM CHAIRMAN: Dr. Charles H. Prien, Head, Chem. Div., Denver Res. Inst., Univ. of Denver, Denver 10, Colo.

Annual—New York, N. Y., Statler Hotel, Dec. 12-15, 1954.

TECHNICAL PROGRAM CHAIRMAN: G. T. Skaperdas, Assoc. Dir., Chem. Eng. Dept., M. W. Kellogg Co., 225 Broadway, N. Y. 7, N. Y.

ASST. CHAIRMAN: N. Morash, Titanium Div., National Lead Co., P. O. Box 58, South Amboy, N. J.

Louisville, Ky., Kentucky Hotel, March 20-23, 1955.

TECHNICAL PROGRAM CHAIRMAN: R. M. Reed, Tech. Dir., Gas Proc. Div., The Girdler Corp., Louisville 1, Ky.

Houston, Texas, Shamrock Hotel, May 1-4, 1955.

TECHNICAL PROGRAM CHAIRMAN: J. L. Franklin, Res. Assoc., Humble Oil & Refining Co., P. O. Box 1111, Baytown, Texas.

Lake Placid, N. Y., Lake Placid Club, Sept. 25-28, 1955.

TECHNICAL PROGRAM CHAIRMAN: L. J. Coulthurst, Chief Proc. Designer, Foster Wheeler Corp., 165 Broadway, New York 6, N. Y.

Annual—Detroit, Mich.—Statler Hotel, Nov. 27-30, 1955.

TECHNICAL PROGRAM CHAIRMAN: T. J. Carron, Supervisor, Chem. Eng. Section, Ethyl Corp., Res. Labs., 1600 West Eight Mile Road, Detroit 20, Mich.

Los Angeles, Calif., March, 1956.

TECHNICAL PROGRAM CHAIRMAN: T. Weaver, Proc. Eng., The Fluor Corp., Ltd., Box 7030, East L. A. Station, Los Angeles 22, Calif.

Annual—Boston, Mass., Hotel Statler, Dec. 9-12, 1956.

TECHNICAL PROGRAM CHAIRMAN: W. C. Rousseau, Proc. & Sales Eng., Badger Mfg. Co., 230 Bent St., Cambridge 41, Mass.

SYMPOSIA

Nuclear Engineering

CHAIRMAN: D. L. Katz, Chairman (Address: See Ann Arbor Meeting).

MEETING—Ann Arbor, Mich.

Agglomeration

CHAIRMAN: A. P. Weber, International Engineering, Inc., 15 Park Row, New York, N. Y.

MEETING—Glenwood Springs, Colo.

Uranium Processing and Refining

CHAIRMAN: R. H. Long, Vitro Eng. Div., Vitro Corp., 120 Wall St., New York, N. Y.

MEETING—Glenwood Springs, Colo.

Oil Shale and Shale Oil Processing

CHAIRMAN: W. I. R. Murphy, Pet. & Oil Shale Exp. Station, U. S. Bureau of Mines, P. O. Box 621, Laramie, Wyoming.

MEETING—Glenwood Springs, Colo.

Reaction Kinetics

CHAIRMAN: N. R. Amundson, Dept. of Chem. Eng., Univ. of Minnesota, Minneapolis 14, Minn.

MEETING—New York, N. Y.

Gas Absorption

CHAIRMAN: R. L. Pigford, Div. of Chem. Eng., Univ. of Delaware, Newark, Del.

MEETING—New York, N. Y.

Solvent Extraction

CHAIRMAN: Dr. R. B. Beckmann, Dept. Chem. Eng., Carnegie Inst. of Tech., Schenley Park, Pittsburgh 13, Pa.

MEETING—New York, N. Y.

New Processes Utilizing Moving Beds

CHAIRMAN: N. Morash, Tit. Div., National Lead Co., P. O. Box 58, South Amboy, N. J.

MEETING—New York, New York

Heat Transfer

CHAIRMAN: R. L. Pigford, Div. of Chem. Eng., Univ. of Delaware, Newark, Del.

MEETING—Louisville, Ky.

Nucleation Processes

CHAIRMAN: D. W. Oakley, Plant Mgr., Metal & Thermit Corp., 1 Union St., Carteret, N. J.

MEETING—Houston, Tex.

Photochemical Processes

CHAIRMAN: Prof. J. J. Martin, Dept. Chem. Eng., Univ. of Michigan, Ann Arbor, Mich.

MEETING—Detroit, Mich.

Unscheduled

Centrifugation

CHAIRMAN: J. O. Maloney, Chairman, Dept. Chem. Eng., Univ. of Kansas, Lawrence, Kan.

Extraction of Hydrocarbons for Chemical Use from Pipe Line Gases

CHAIRMAN: E. E. Frye, J. F. Pritchard & Co., 210 W. 10th, Kansas City 5, Mo.

Submitting Papers

Members and nonmembers of the A.I.Ch.E. who wish to present papers at scheduled meetings of the Institute should follow the following procedure.

First, write to the Secretary of the A.I.Ch.E., Mr. S. L. Tyler, American Institute of Chemical Engineers, 120 East 41st Street, New York, requesting three copies of the form "Proposal to Present a Paper Before the American Institute of Chemical Engineers." Complete these forms and send one copy to the Technical Program Chairman of the meeting for which the paper is intended. one copy to the Assistant Chairman of the A.I.Ch.E., Program Committee, address at the top of this page, and one copy to the Editor of Chemical Engineering Progress, Mr. F. J. Van Antwerpen, 120 East 41st Street, New York.

If you wish to present the paper at a particular symposium, request 4 copies of the proposal sending a copy to the Chairman of the symposium.

Before Writing the Paper

Before beginning to write your paper you should obtain from the meeting Chairman, or from the office of the Secretary of the A.I.Ch.E., at 120 East 41st St., New York, a copy of the A.I.Ch.E. Guide to Authors, and Guide to Speakers. These cover the essentials required for submission of papers to the A.I. Ch.E. or its magazines.

Copies of Manuscript

Five copies of each manuscript must be prepared. For meetings, one should be sent to the Chairman of the symposium, and one to the Technical Program Chairman of the meeting at which the symposium is scheduled. If no symposium is involved, the two copies should be sent to the Technical Program Chairman. The other copies should be sent to the Editor's office since manuscripts are automatically considered for publication in Chemical Engineering Progress, or the symposium series of Chemical Engineering Progress, but presentation at a meeting is no guarantee that they will be accepted.

DEADLINE DATES FOR PAPERS

NEW YORK MEETING—August 12, 1954

LOUISVILLE MEETING—November 20, 1954

HOUSTON MEETING—January 1, 1955

LAKE PLACID MEETING—May 25, 1955

DETROIT MEETING—July 27, 1955

LOS ANGELES MEETING—No definite date as yet

BOSTON MEETING—August 9, 1956

NEWS

(*Continued from page 88*)

CANADIAN CHEMICAL ENGINEERS TO MEET

A symposium on the chemical engineer in Canada will be held during the annual conference and exhibition of The Chemical Institute of Canada at the Royal York Hotel, Toronto, from June 21 to 23, 1954. Topics to be considered will be factors of future growth, university training of Canadian chemical engineers, and the mutual responsibilities of Canadian industry and its engineers.

Other sessions of the chemical engineering division will be a unit operations meeting, at which the key speaker will be Max Leva, and a unit processes session, which will be applied particularly to the petroleum industry. At the latter session there will be a paper on the Sherritt Gordon nickel-recovery process.

Information on the meeting may be obtained from The Chemical Institute of Canada, 18 Rideau St., Ottawa 2, Ontario.

N.S.F. SURVEYS GRADUATE ENROLLMENT IN U. S.

A survey of the financial support available to graduate students in about 500 American colleges and universities offering study beyond the bachelor's degree is being initiated by the National Science Foundation as part of a series of studies that the Foundation is making of all phases of the nation's scientific activities, resources, and needs. Accurate information about the potential number of highly trained personnel is essential in considering the expansion of research resources, the present shortage in scientific manpower, and the recruitment of young scientists. The questionnaire will be sent to all heads of graduate departments in the natural sciences, the social sciences, and the humanities to enable comparison of the amount of assistance available to graduate students in the sciences with that available in other fields.

Information will be obtained on the total number of graduate students, the number of fellowship holders, the number of teaching and research assistantships available to graduate students, and the amounts and sources of funds for fellowships and assistantships from the Federal Government, from institutions, or from industry and private foundations, including the number of applications received and the number of unfilled positions and grants for this year.

The questionnaire will be pretested at the George Washington University, the University of Pennsylvania, and the University of Indiana.

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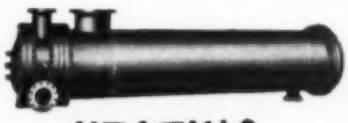

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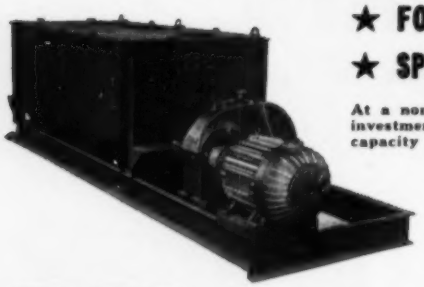

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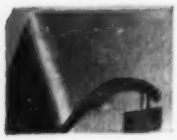

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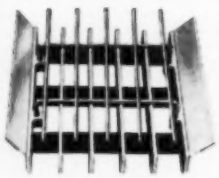

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LOCAL SECTION

The third meeting of 1954 of the Baton Rouge Section was a joint one with the American Chemical Society. About 100 members and guests heard Neal Amundson of the University of Minnesota, speak on the subject "Chemical Reactors, A Mathematical Analysis." It has been announced that James Mair of the Goslin-Birmingham Co. will be the speaker at a subsequent meeting.

At the third meeting of 1954 of Atlanta Section, J. B. Harlow, district manager, Union Carbide and Carbon Corporation talked on coal hydrogenation. He included in his discussion the improvements effected by experimentation on his company's 300 ton/day pilot plant in Institute, W. Va. After a question-and-answer period Mr. Harlow showed the group a Carbide and Carbon film on continuous mechanical coal mining. Twenty-six members and guests attended this meeting held April 8 at Brittain Dining Hall on the Georgia Tech Campus. H. H. Sineath, reporter and publicity chairman of the Atlanta Section, stated that members of the Atlanta Section are taking a more active part in committee work of the Institute "from which they are receiving much personal satisfaction." Sineath also wrote in his communication that future speakers at the Atlanta meetings will receive a memento in the form of an ash tray, shaped like the state of Georgia and inscribed "Atlanta Section, A.I.Ch.E."

The section was fortunate, so says Sineath, in having as its honored guest at a previous meeting George Granger Brown, dean of engineering, University of Michigan and present Treasurer of A.I.Ch.E. He gave a talk on Institute matters—proposed membership designation changes, sponsorship of nuclear engineering, and various other concerns of general interest. Dr. Brown's speech was followed by a film, "Decision for Chemistry," from Monsanto. Fifty-nine members and guests attended this meeting held at Mammy's Shanty on Peachtree Street.

R. M. Berry, reporter of the Rocky Mountain Section, sent in word about the April 8 dinner meeting. After dinner the host was the Criminal Division of the Denver Police Department, whose demonstration included the lie detector and a visit to the lab. and files. Vice-chairman Leo Roth brought the members up to date on the efforts to form a unified engineering and scientific organization in Colorado.

Commenting on the report of the President's Materials Policy Commission, commonly called the Paley Commission Report, A. R. Powell, associate research manager, Koppers Co., spoke

at the sixth monthly meeting of the Pittsburgh Section for the year 1953-1954, held in the Mellon Memorial Institute Auditorium. Titled, "The Chemical Engineer's View of Resources for the Future," Dr. Powell said that while the consumption of raw materials will be increasing, the resources to supply the raw materials must be increased also; that there are three ways of doing this—namely, by exploration, by fuller recovery, and by importing. He added that the chemical engineer fits into the picture by contributing to fuller recovery through the application of energy, technology, and capital investment. He included among those industries which should show the greatest expansion over the next twenty-five years the organic chemicals. Messrs. Morrissey and Black sent in a full report of this meeting designated as Annual Student Night. It was opened by welcoming the students from West Virginia University, Grove City College, Carnegie Institute of Technology, and the University of Pittsburgh. McAfee, section vice-chairman, introduced the panel of section members to answer students' questions about the different types of work open to chemical engineers.

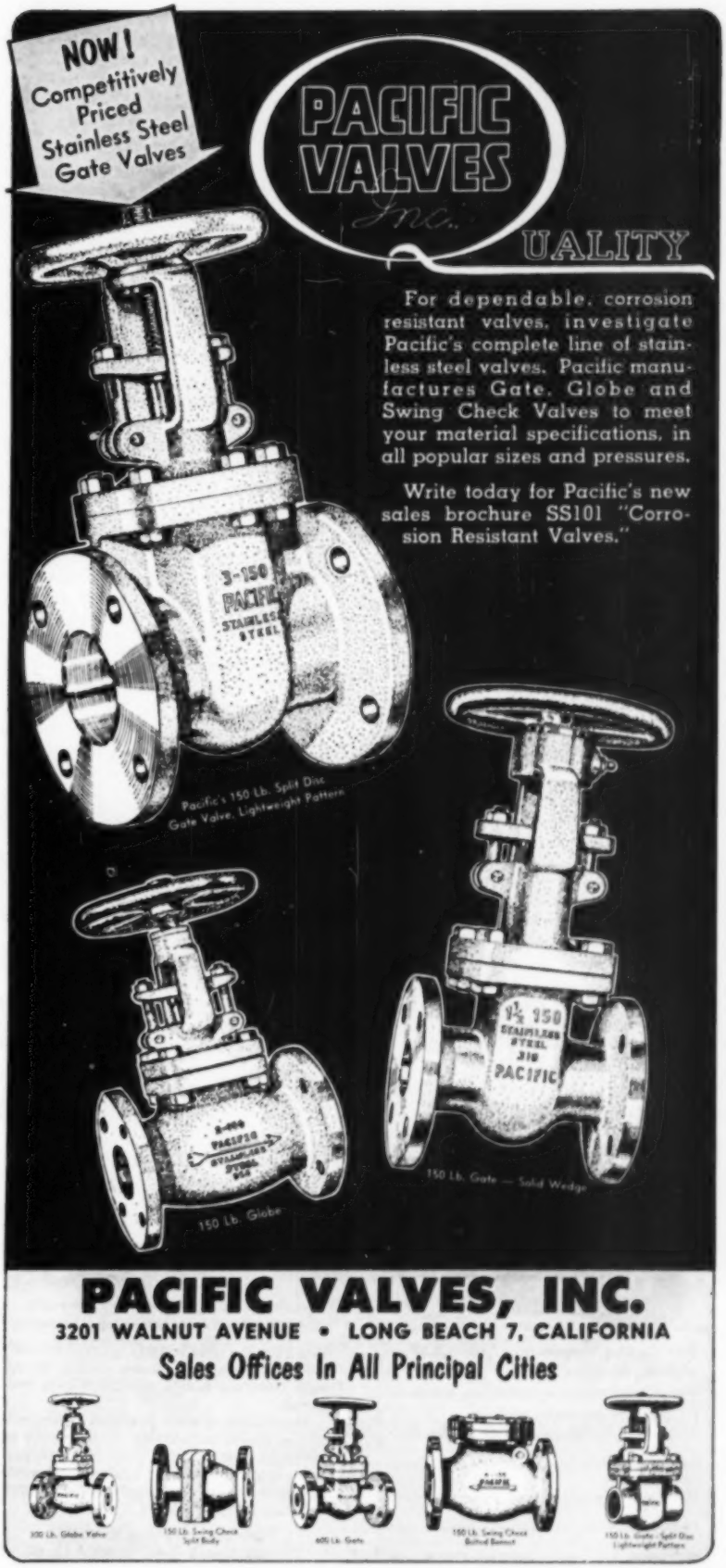
Outlining the service properties of the various types of plastics and discussing their application and limitations under a variety of conditions, Robert Leininger, assistant chief of the plastics and rubber division, Battelle Memorial Institute, recently addressed twenty-five members and guests of the Central Ohio Section on "Engineering Applications of Plastics." Edwin E. Smith reports that the meeting was held at Pomerene Hall, the Ohio State University.

An inspection trip through the centrifugal pump division of the Mission Manufacturing Co., Houston, Tex., featured the April 23 meeting of the South Texas Section. At the dinner session held at the Log Cabin, a panel discussion on centrifugal pumps was held with Neal Heaps, Mission Manufacturing Co., and Jack Walmsley, pump specialist, engineering division, Humble Oil & Refining Co., Baytown, as principals.

C. L. Fitzgerald, Jr., secretary of the section, sent in the notice.

"The Idiosyncrasies of Fractional Distillation" was the subject of an address given by Donald B. Keyes, industrial consultant, Arthur D. Little Co., before the April 8 meeting of the Western New York Section.

Norman C. Updegraff, assistant technical director of the gas processes division of the Girdler Co., spoke before the April 27 meeting (44th) of the East Tennessee Section on basic chemicals from natural gas. Since 1946 Mr. Updegraff has been with the Girdler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Co. specializing in process design of plants for production, purification, and use of various industrial gases. Reporter M. L. Gernert states that the talk was most timely because of the introduction of natural gas in that area.

Gernert also reports that the 43rd general meeting consisted of a field trip through Borden Mills. Arranged by J. H. Jensen, the meeting was attended by fifteen members.

The problems which the A.I.Ch.E. will face as it expands were covered by C. G. Kirkbride at the April 15 installation banquet and student chapter night of the Rhode Island Section. Dr. Kirkbride noted that the membership doubles approximately every seven years; that, because of this fact and in order to serve better the membership, the Institute plans increases to the physical plant and enlarging the number of staff members. Dr. Kirkbride is President of A.I.Ch.E.

At this meeting members of the student chapter from the University of Rhode Island were introduced. T. S. Crawford, chairman of the section, spoke briefly of the society's history, tracing its development from its inception as the Rhode Island Society of Chemical Engineers to its present status as a local section of the Institute.

"Tools for Research and Development in the Chemical Engineering Field" was the subject of an address given by Roy Kinckiner, deputy director of research, Du Pont Co., at the previous meeting. At the conclusion of his talk Dr. Kinckiner presented a film "Bubbles" which showed the work done at Du Pont on attempts to improve efficiency of operations where bubbling and bubbles are desirable or encountered because of the conditions of operation.

Morton Port sent in a report on both meetings.

Wilburn C. Schroeder, professor, University of Maryland department of chemical engineering, discussed "Prospects for the Commercial Utilization of Shale" at the April 5 dinner meeting of the Chemical Engineers Club of Washington held in the Maryland University Dining Room.

At the April 13 meeting of the Philadelphia-Wilmington Section, W. T. Dixon was elected chairman for the coming year and E. F. von Wettberg, Jr., was named chairman-elect.

Other officers for next year include the following:

Corresponding Secretary—W. E. Osborn, Atlantic Refining Co.

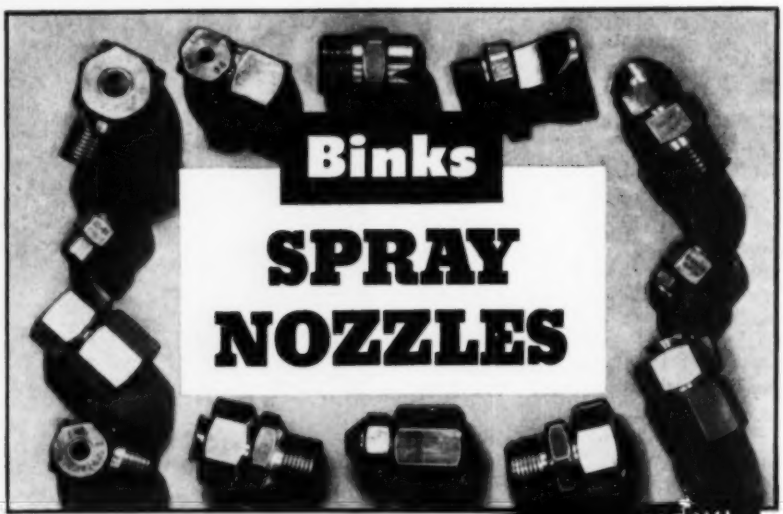
Recording Secretary—D. A. Drew, Hercules Powder Co.

Treasurer—W. A. Casey, Sun Oil Co.

Asst. Treasurer—R. A. Crane, Du Pont Co.

Executive Committee—J. I. Harper, Sun Oil Co.; R. E. Chaddock, Hercules Powder Co.; J. J. Hur, Atlantic Refining Co.

Our correspondent, E. R. Westfield, sent in with his story a few facts about Messers Dixon and von Wettberg. Briefly, Mr. Dixon is manager of



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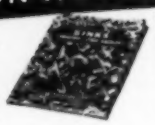

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the design division in the engineering and construction department of the Atlantic Refining Co., and a Director of A.I.Ch.E. (1953). Mr. von Wettberg is assistant director of the engineering research laboratory at the Du Pont Experimental Station in Wilmington.

At this meeting H. C. Hottel, professor of fuel engineering and director of the Fuel Research Lab at M.I.T., told the 200 engineers present about the latest developments in the field of solar energy.

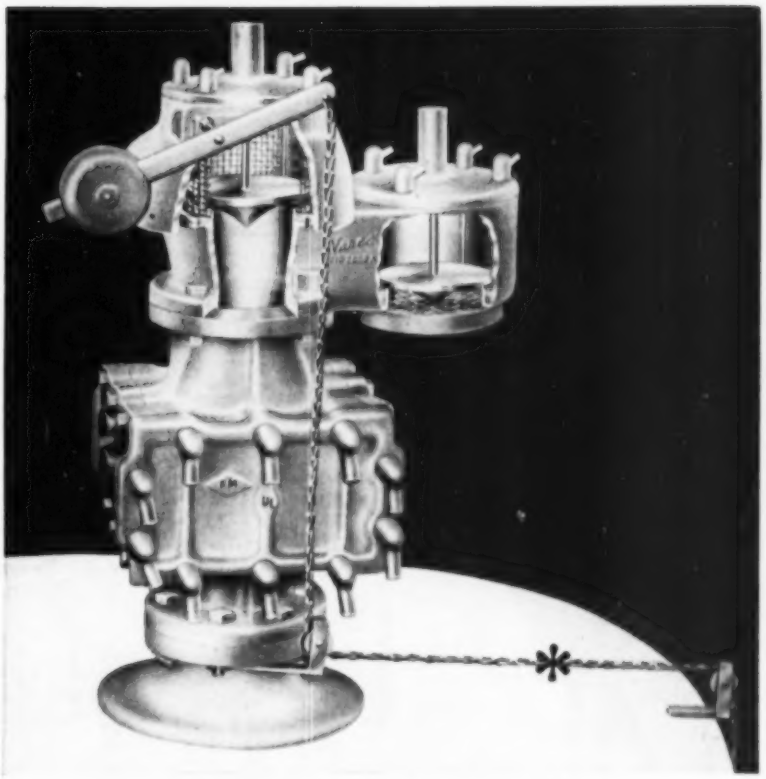
Reviewing the various reactors that are now in existence or contemplated for future use, L. W. Niedrach, chemistry and chemical engineering section, Knolls Atomic Power Laboratory, spoke on "Atomic Power—Present and Future" before the April 6 meeting of the Northeastern New York Section in the auditorium of the research laboratory, General Electric Co. Dr. Niedrach presented figures comparing the estimated cost of electric power from reactors with those obtained from conventional power plants. F. C. Steiner sent in news of this meeting.

With the advancement of rocket science it has now become theoretically practical and possible to establish space stations as jumping off spots for trips to the moon, Mars and other planets. With these words W. R. Jackson, senior design engineer of the E. W. Bliss Co., Canton, Ohio, addressed sixty members and guests of the Akron Section on April 8. Titled "Artificial Satellites," the talk, according to Nicholson, the reporter, proved unusually interesting to all present especially when Mr. Jackson continued with the statement that to travel to the moon an artificial satellite must be created to serve as a refueling station in space some 1,000 miles above the earth's surface. It would likewise have tremendous value in the event of war, he added. R. P. Dinsmore, Director of A.I.Ch.E., gave a brief report on the Council meetings and outlined the numerous activities being undertaken by the Institute in all phases of its operation.

Fifty members of the St. Louis Section held "Old Timers' Night" with a cocktail hour and multicourse dinner at the Missouri Athletic Club, April 20, 1954. Eugene W. Lieben, Monsanto, spoke briefly on highlights of his recent assignment in Great Britain, Robert L. Burnes, the St. Louis Globe-Democrat's sports editor, columnist, and radio commentator regaled the group with anecdotes about well-known sports people and more serious comments on such topics as honesty in sports. R. G. Kerlin reports that there was a lively question-and-answer period.

D. F. Chamberlain, program chairman who became section chairman this month, announced that the May meeting will feature a buffet supper at the York Hotel, followed by an evening plant trip through Granite City Steel Co., with ladies invited.

H.R.G.



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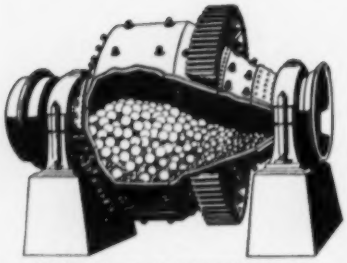

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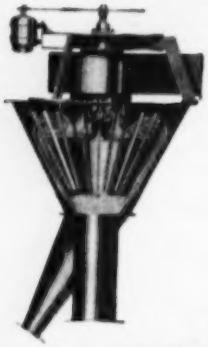

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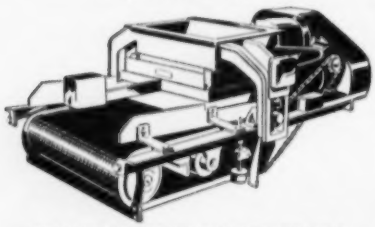

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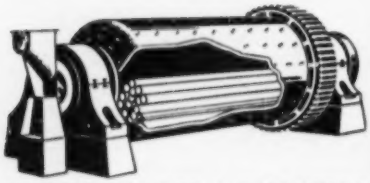

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PEOPLE

Ernest H. Volwiler, president of Abbott Laboratories, North Chicago, Ill., will receive on Oct. 12 the Chemical Industry Medal for 1954 "for conspicuous services to applied chemistry." His active career included teaching at Miami University and University of Illinois in his predoctorate years. This was followed by thirty-six years at Abbott where he served as chief chemist, director of research, vice-president in charge of research and development, executive vice-president, and president and general manager. He will be the twenty-first recipient of the Chemical Industry Medal.

Kenneth S. Valentine, formerly sales manager of The Turbo-Mixer Corp. and New York manager of The Patterson Foundry and Machine Co., has set up his own business as manufacturers' representative. Mr. Valentine was the first president of the Chemical Equipment Sales Engineers Association of New York. He is co-author of the mixing section of Perry's "Chemical Engineers' Handbook." Sixteen patents on mixing devices and methods have been issued to him and he has written numerous articles on mixing, dissolving and gas absorption.

The Graver Water Conditioning Co., New York, has announced the appointment of **Robert J. Keating** as head of its newly formed industrial waste department. In this position he will be in charge of all Graver activity in the rapidly expanding field of waste treatment for industry. He served as a major in the U. S. Army for five years and was with the Engineer and Chemical Corps, specializing in the construction and operation of chemical plants. After seven years in sales and engineering for Orchard Bros., Inc., he joined Graver in January of 1953.

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P. J. Kern, Jr., was recently appointed to the staff of The Colonial Iron Works Co., Cleveland, Ohio, to head Karbate service activities. Before he held this position, he served as a design and service engineer in the Karbate division of the National Carbon Co.

The appointment of **William J. Hanlon** as chief process engineer of the Ashtabula chemical plant of The General Tire & Rubber Co. was recently announced. He will be located at General's polyvinyl chloride resin operation at Ashtabula. With the company since 1952, he formerly worked for the J. T. Baker Chemical Co., Phillipsburg, N. J., and for Mathieson Chemical Corp., Niagara Falls, N. Y.

Thomas R. Young, chemical engineer with Singmaster & Breyer for nine years, has recently been elected a partner in the firm. Mr. Young has had fifteen years' production, design, and management work. He spent seven years with Du Pont ending as a production supervisor of its tetraethyl lead plant.

Howard F. Bjork

Howard I. Cramer

Appointments of **Howard F. Bjork** as vice-president, manufacturing, and of **Howard I. Cramer** as vice-president, development, Sharples Chemicals, Inc., Philadelphia, Pa., have recently been announced. Mr. Bjork, a graduate of the University of Michigan, has held various positions at the Sharples plant for the last seventeen years including that of plant manager since 1950.

Dr. Cramer has been a member of the company's development department for thirteen years and its director since 1944. He served in 1951 as chief of the aliphatic organic chemicals section of the Office of Price Stabilization. He is a graduate of the universities of Akron and Wisconsin.

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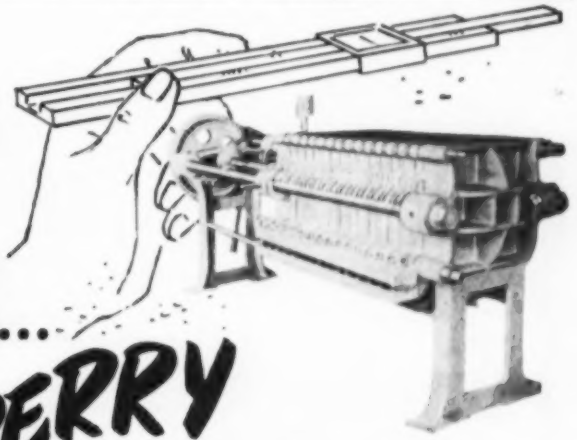

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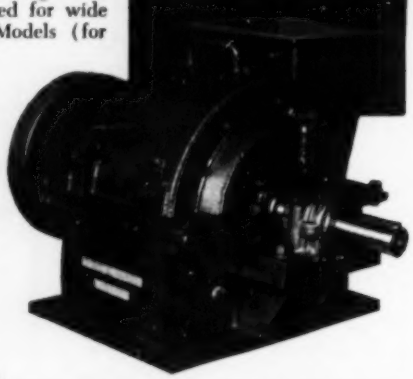

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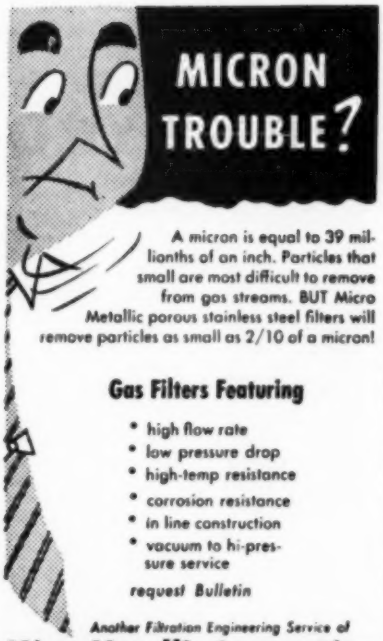
PIRET ON LECTURE TOUR

Edgar L. Piret, professor of chemical engineering at the University of Minnesota and engineering consultant for Minnesota Mining & Manufacturing Co., sailed from New York, March 24 for a European lecture tour. Sponsored by the Royal Institute of Dutch Engineers and the Association of Swedish Engineers, this lecture series will take Dr. Piret to the leading universities of Sweden and Holland. He will also address professional engineering groups at the universities of Paris and Nancy, France; Frankfurt, Germany; Zurich, Switzerland; and Helsinki, Finland. He will also join discussion groups at Cambridge and Bristol universities, England, and at Liège in Belgium.

In 1950 and 1951 Dr. Piret lectured at the universities of Paris and Nancy under the Fulbright Act. At that time he was instrumental in initiating courses in chemical engineering in French universities. For his pioneering work he was decorated by the French ministry of education and was awarded the Friedel Medal by the University of Paris. He has been a faculty member at the University of Minnesota since 1937.

Walter C. Huffman, formerly general foreman of the new petrochemical plant, Sun Oil Co., Philadelphia, Pa., has been made assistant superintendent in charge of petrochemicals. He joined the company in the development laboratory at Marcus Hook in 1942 and later became leader of the department's "cracking group," directing development work on components and the blending of military aviation fuels. He became chief of the laboratory's technical service section in 1948. He also served Petroleum Administration for Defense in 1950 as a consultant in increasing aviation gasoline production.

Dana Berg, associate editor, has recently become managing editor of *Chemical Processing,* Chicago. Before joining Putman Publishing Co. five years ago, Mr. Berg was associated with Linde Air Products, doing research and development work on the Manhattan District Project and research and development of postwar products.



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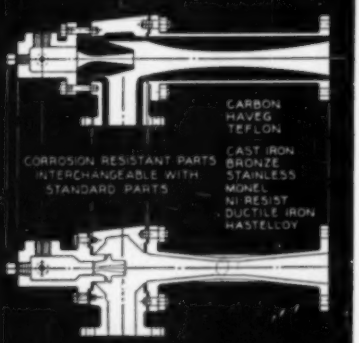

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MONSANTO PERSONNEL FOR NEW DIVISION

Monsanto Chemical Co. has appointed several members of its staff to key positions in the newly created research and engineering division:

F. B. Langreck, formerly technical adviser to the director of the former general development and patent department, will now be technical adviser to the division general manager.

Hal G. Johnson, who has been director of research for the former Western division, becomes director of development, and will be located in St. Louis.

W. M. Cooper, chief engineer for the organic chemicals division, becomes director of engineering.

Carlton M. Dean, who was manager of engineering sales in the organic chemicals division, is now director of engineering sales.

The appointment of **James H. Gardner** as assistant director of the petrochemicals department, National Research Corp., Cambridge, Mass., was recently announced. Dr. Gardner joined the company in 1951 as a project manager. Prior to that time he was with the Shell Oil Co. as a technologist in the company's Houston, Tex., refinery.

The appointment of **Robert C. Davidson** as sales manager, Filtrol Corp., Los Angeles, Calif., was recently announced. Prior to his affiliation with Filtrol he was a process engineer at Arabian American Oil Co.

The board of trustees of the Southern California Air Pollution Foundation, Los Angeles, Calif., recently announced the appointment of **William Lawrence Faith** as deputy director and chief engineer. Dr. Faith has been director of engineering, chemical division, Corn Products Refining Co., Argo, Ill., since 1948, and, during the years 1942-1945 he served the Office of Production Research and Development, W.P.B., Washington, D. C., as consultant, assistant director, and deputy director. Associated for many years with the teaching profession, he has been special research assistant in chemical engineering, Engineering Experiment Station, University of Illinois; assistant professor, chemical engineering, Kansas State College; professor, chemical engineering, State University of Iowa. Dr. Faith has served on several A.I.Ch.E. committees, such as Student Chapter, and Admissions.

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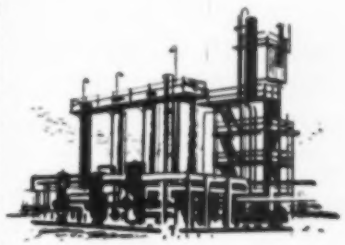

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E. W. Douglass is now engaged in engineering consulting in the chemical and metallurgical fields, residing in Carlsbad, N. M. Recently he resigned his post as research director for the Potash Company of America. Prior to 1943, when he first joined Potash, he was employed in various research and technical capacities by the Ozark-Mahoning Company of Tulsa, Okla., engaged in its salt cake, sulfuric acid, and other heavy chemical operations. Previously he had been affiliated with the Anglo-Chilean Consolidated Nitrate Corp. and the Latauro Nitrate Corp. in Chile.

Benedict F. Melucci is now technical director, industrial chemicals division, American Cyanamid Co., New York. A graduate of Columbia University (1943) with a B.S. degree in chemical engineering, Mr. Melucci joined Cyanamid in 1946. He has served with Falco Metal Products in the synthetic organic chemicals department and the manufacturers chemicals department where he was a senior technical representative before becoming technical director.

The appointment of **Edward C. Ashton** as manager of sales of heat-transfer equipment, Downingtown Iron Works, Inc., division of Pressed Steel Tank Co., was recently announced. Mr. Ashton has been with Downingtown since 1944, serving as assistant manager until 1949, when he was put in charge of sales and engineering for heat-transfer products. Mr. Ashton earned his B.S. degree in mechanical engineering at the University of Pennsylvania.

Webster N. Jones, director of college of engineering, Carnegie Institute of Technology and industrial consultant, has accepted the chairmanship of the Gordon Research Conferences, AAAS, on Aromatic Chemicals to be held at the New Hampton School, New Hampton, N. H., June 14-18.

William L. Davidson has been appointed research director, development department, Westvaco Chlor-Alkali division of Food Machinery and Chemical Corp., New York. Prior to joining Food Machinery on Jan. 1, 1954, Dr. Davidson was for three years director of the Office of Industrial Development of the A. E. C. in Washington. He was previously associated with the B. F. Goodrich Co. and Monsanto Chemical Co.

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S. E. Taub, a chemical engineer with Foster D. Snell, Inc., since 1951, will now handle purchasing for the Hull Co., Foster D. Snell Research, Inc. In addition, he will supervise all pilot plant operations.

John Hegedus, a recent graduate of Columbia University with a B.S. degree in chemical engineering, has joined the firm as a junior chemical engineer in process design.

L. Petrone has been engaged as a junior chemical engineer to undertake research in engineering physics. He is a graduate of Polytechnic Institute of Brooklyn with a B.S. degree in chemical engineering.

The 1954 Carl-Engler-Medaille, Germany's highest award in the field of mineral oil science, will be awarded to **Gustav Egloff,** director of research for Universal Oil Products Co., Des Plaines, Ill. Dr. Egloff will receive the medal in October during the annual congress of the German Institute of Petroleum and Coal to be held in Essen, West Germany. He will address the congress on "Chemistry in the Modern Oil Industry." Subsequently Dr. Egloff will make an intensive study of the latest advance in Germany's chemical fields. He also plans to give a series of lectures before West German universities and technical schools.

John Davis has joined Shell Development Co.'s experimental plants department as a junior engineer. He received his B.S. degree in chemical engineering in 1950 from Rhode Island State College and in June of this year he will receive his M.E. degree in chemical engineering from Yale University.

NEW V.P.'s AT JEFFERSON

Jefferson Chemical Co., Inc., recently announced the designation of **William H. Bowman** as vice-president, operations, and of **Max Neuhaus** as vice-president, development.

Dr. Bowman will be responsible for current operations of the company dealing with the manufacture and sale of its regular products. His responsibilities will cover sales, production, purchasing and traffic.

Dr. Neuhaus will be concerned with the development of new products to the point where they are turned over to operations for commercial manufacture and sale. Included in his responsibilities is the work of the company's research laboratories located at Austin, Tex., as well as engineering, market research, market development and related activities.

(*Continued on page* 104)

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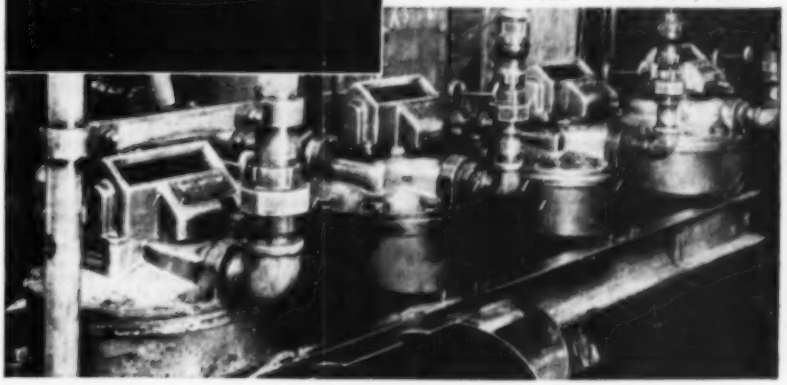

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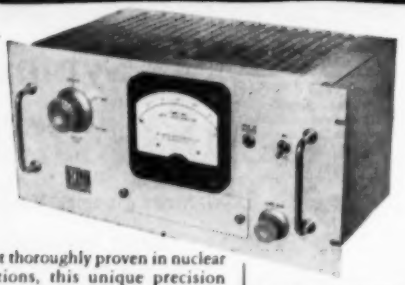

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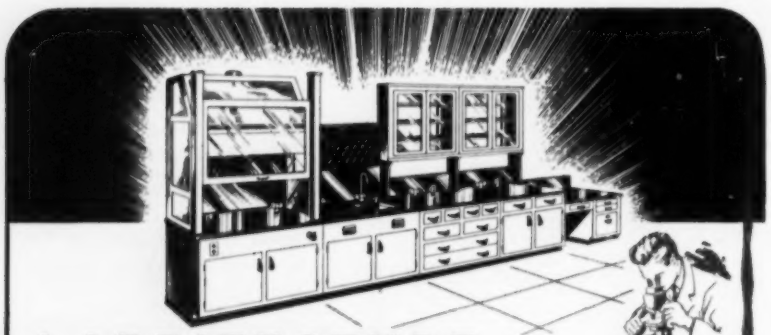

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PEOPLE

(Continued from page 101)

William N. Williams, head of the Westvaco mineral products division of Food Machinery and Chemical Corp., was elected a vice-president of the corporation at a recent meeting of the board of directors in San Jose, Calif. As a management staff member of the former Westvaco Chemical Corp., Mr. Williams became associated with Food Machinery in 1948 when Westvaco was merged into FMC and reorganized as an operating division of the parent corporation. In 1953, he was placed in charge of the newly formed Westvaco mineral products division after the reorganization of the former Westvaco chemical division into two distinct organizations: Westvaco mineral products division and Westvaco chlor-alkali division. Prior to that Mr. Williams was vice-president in charge of operations of the Westvaco division of FMC.

Duane L. Green will become head of the chemistry and chemical engineering departments at Clarkson College of Technology, Potsdam, N. Y., at the end of the current college semester. Dr. Green, who will simultaneously be promoted from associate professor to full professor, will assume the duties of acting chairman of the two departments on July 1, succeeding **Charles H. Hecker,** who is retiring in June. Dr. Hecker will have then completed twenty-five years of service at Clarkson.

Dr. Green went to Clarkson in 1946 as an instructor in the chemical engineering department. While on leave of absence from teaching duties, he did research and development work for the Du Pont Co. on textile fibers and on the preparation, characterization and spinning of high polymers. After this industrial experience, he returned to Clarkson Tech faculty in February, 1953. He has also taught at Penn State and the University of Buffalo.

Theodore Lemiszka is a recent addition to the staff of Esso Laboratories, Standard Oil Development Co. Graduated from Rensselaer Polytechnic Institute with a bachelor's and a master's degree in chemical engineering, he is at the present time studying at Princeton University for his doctorate.

David M. Williamson mentioned in the March issue of C.E.P. (page 81) as being appointed area manager of industrial sales for the Baldwin-Hill Co. is not the David M. Williamson who has been associated with Monsanto Chemical Co. for the past twenty-seven years. The error was due to the similarity in name and initial.

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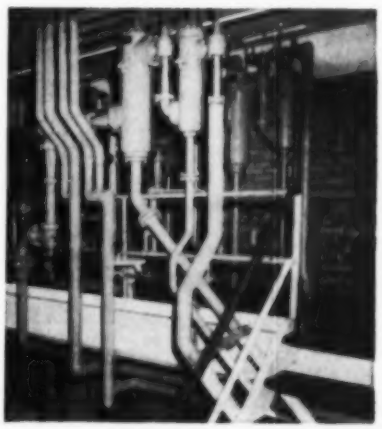

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A.I.Ch.E. News And Notes

Chicago was host last month to the executive boards of the five engineering societies. Purpose was an inspection of three possible sites for the much-discussed Engineering Center.

Locations at three schools were shown - Northwestern, Illinois Institute of Technology, & University of Chicago.

Positive action on a choice was deferred however since the societies have not yet made the decision to move out of New York.

An important step was taken nevertheless. The Presidents of the societies were asked to serve on an action committee & to obtain sanction from their respective boards.

A.I.Ch.E. agreed & at the April council meeting adopted the following resolution, "that the Council of the A.I.Ch.E. authorizes its President to join with the presidents of A.S.C.E., A.I.M.E., A.S.M.E. & A.I.E.E. in the formation of a Committee of the Five Presidents for the purpose of expediting the determination of a location & other questions necessary for a joint decision by the Boards of the Five Societies to providing an adequate Engineering Center Bldg."

Above action is necessary to bring the chemical engineers into the picture; A.I.Ch.E. has neither equity in the present engineering building in New York nor representation in the United Engineering Trustees, real estate agent for the four founder societies. Since the four societies look upon U.E.T. as the legal agent for conducting the search for new headquarters, some new line of authority had to be created to enable cooperation with the fifth society.

L. P. Scoville, chairman of the program committee for the past year, asked Council to accept his resignation. Loren recently took over as director of engineering for Diamond Alkali & felt the need to decrease outside activities for a while.

George Armistead, Washington, D. C. consultant, was appointed by Council as program chairman. Armistead was responsible for the recent Washington meeting program & had also been assistant chairman of the National program meeting.

It's the Greenbrier, White Sulphur Springs, for a National Meeting, April, 1958.

Council's technique for keeping posted on committee activities is through liaison members.

Every member on Council is responsible for at least one committee; acts as father confessor, complaint adjuster, spark plug, & proponent.

W. L. Faith told of progress within Institute section committees.

Stan Lopata has monthly newsletter going to committee members, officers of local sections, etc. on L. S. Committee actions and plans. One thing now underway - a collection of information on local section speakers, availability, subjects, etc. A. K. Doolittle thumbnailed progress for the Professional Development Committee. Roland Vorhees, chairman, has several studies underway covering the professional attitudes & development of Ch.E.'s, & these will culminate during the year.

George Oberfell wound up reports to Council this month with sketch of plans of Waste Disposal Committee.

K. S. Watson is pushing plans for extensive coverage by the Institute of air-pollution problems & answers.

Ballots on the Constitutional amendments are rolling in heavily. More than 2,000 have been received. W. G. Fogg & W. D. Kohlins were asked by Council to serve as a Tellers Committee. Voting ends June 8.

E.C.P.D. recently made a suggestion to all engineering societies that student-chapter charters be withdrawn from schools that failed to meet accrediting standards. This concept was rejected by the Council of the Institute as being against the best interests of students in chemical engineering, & also contrary to the historic practices of the A.I.Ch.E.

Nuclear Engineering division reports a heavy interest in membership. In less than four months, according to Joe Martin, associate professor at Michigan & secretary of the division, more than 500 have joined.

South Texas is well on its way to sweeping this year's membership race as it did last year. Closest to it in number of applications for membership are the Chicago & Wilmington sections. J. T. Moody is sparking the drive for the Texans, according to the most recent report of the Membership Committee chairman, J. W. Schall.

Prediction of attendance at the Ann Arbor meeting is a real puzzler. Normally it should draw about 700, but the program is so large, the subject so important that we are betting on 1,400.

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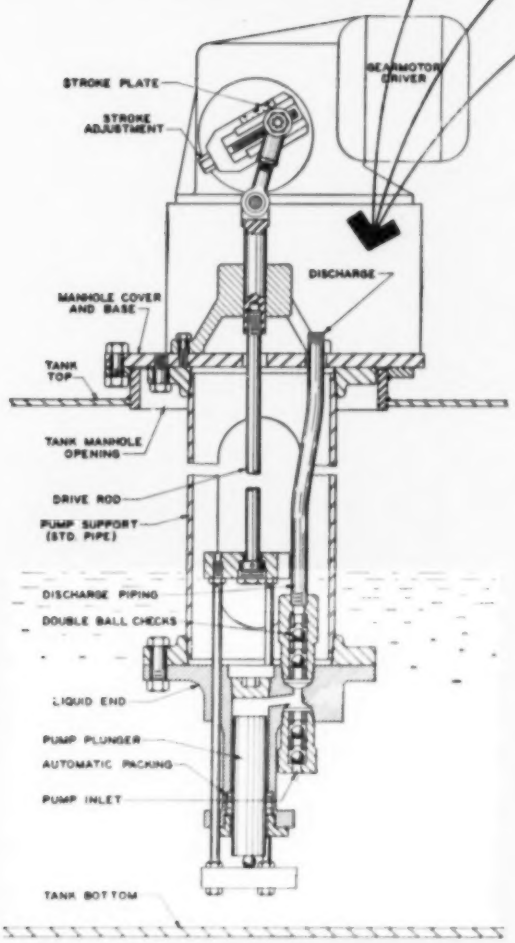

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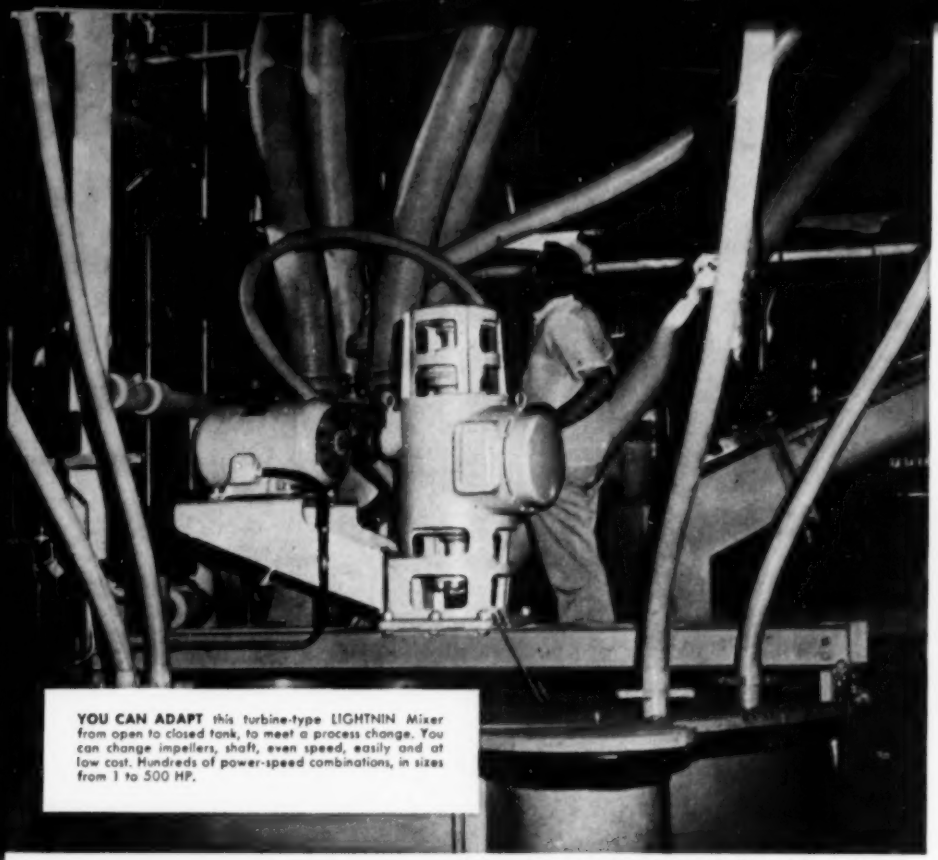
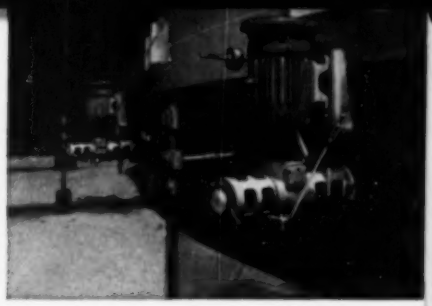


YOU CAN ADAPT this turbine-type LIGHTNIN Mixer from open to closed tank, to meet a process change. You can change impellers, shaft, even speed, easily and at low cost. Hundreds of power-speed combinations, in sizes from 1 to 500 HP.

Photo courtesy International Minerals & Chemical Corporation.



YOU CAN CHANGE quickly from a mechanical shaft seal to a packed stuffing box, and back again, with this LIGHTNIN Side Entering Mixer. This means easier maintenance . . . extra protection. Tank shutoff is out in the open—easy to get at, easy to operate. Sizes 1 to 25 HP.

YOU CAN DO HUNDREDS of mixing jobs quickly with versatile LIGHTNIN Portable Mixers. Instantly make any open tank an efficient mixing vessel. More than 30 standard models with electric or air motor, direct or gear drive. Sizes ⅙ to 3 HP.

Choose a fluid mixer that grows with your process

Today, this mixer is churning up 5,000 gallons of a phosphoric acid slurry.

Tomorrow, with a few simple changes, the *same mixer* may be lifting and distributing solids throughout 3,000 gallons of heavy prefilt slurry.

Or it may be whirling millions of pin-point gas bubbles into intimate contact with 10,000 gallons of fermentation broth.

Provided the horsepower requirements are not too different, you can often switch a LIGHTNIN Mixer from one operation to another, at far less than the cost of a new mixer.

7 ways to beat obsolescence

You can change the mixer mounting from open-tank to closed pressure vessel, and vice versa. You can get a new mounting to fit any tank nozzle.

You can switch from standard to low-headroom mounting, from top entering to bottom entering.

You can change shafts—even increase or decrease shaft diameter—to meet new torque requirements.

You can change size and shape of impellers—and *know in advance* what your results will be.

And with many LIGHTNIN Mixers, you can *change speed*—quickly, simply, without dismantling the mixer or even removing it from the tank. Many of these units give you a choice of up to 16 standard interchangeable speeds.

This versatility helps you beat the high cost of obsolescence in your plant. It is just one of the reasons why LIGHTNIN is the best choice you can make for mixing fluids.

For quick, competent help on fluid mixing—and guaranteed results—call in your LIGHTNIN representative. Or write us today.

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- ☐ DH-51 Explosionproof Laboratory Mixers
- ☐ B-102 Top Entering Mixers (turbine and paddle types)
- ☐ B-103 Top Entering Mixers (propeller type)
- ☐ B-104 Side Entering Mixers
- ☐ B-105 Condensed Catalog (complete line)
- ☐ B-107 Mixing Data Sheet
- ☐ B-108 Portable Mixers (electric and air driven)

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MIXCO fluid mixing specialists